

Advanced Energy Saving Through The Use Of Evaporative Cooling And Energy Recovery In Hybrid HVAC Systems

- ❧ Industrial Process And Energy Optimization
- ❧ Industry Workshop
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Gettysburg, PA
- ❧ Leon E. Shapiro
ADA Systems, LLC
Carol Stream, IL



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Evaporative Cooling:

Why Is This Important To You (and your clients)?

∞ There are external forces affecting the method and manner in which institutions and businesses provide ventilation, heating and cooling for their facilities:

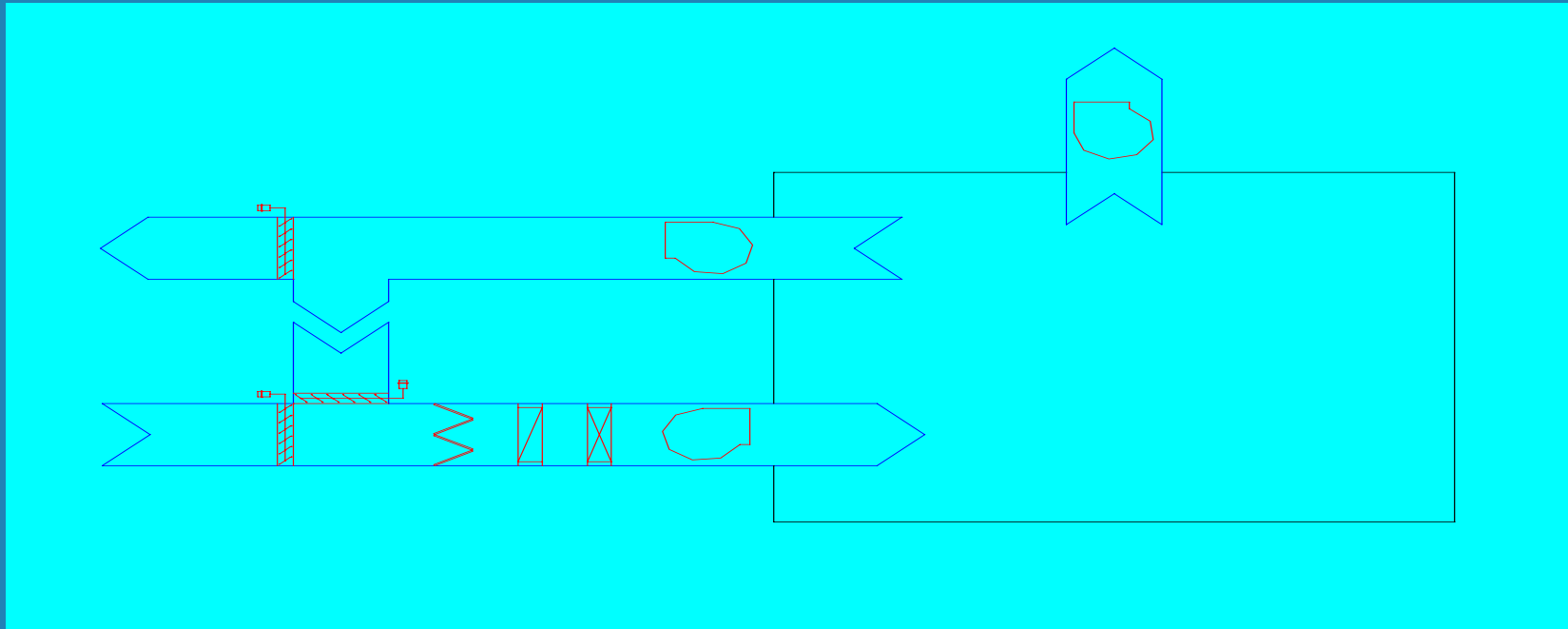
- ASHRAE Standard 62 - 2001
- ASHRAE Standard 90.1 - 1999
- Federal Energy Policy Act of 1992
- LEED Certification
- Global Climate Change Treaty
- Current Events

Evaporative Cooling:

Why Is This Important To You (and your clients)?

- ⌚ If you could, would you provide your clients/customers with an HVAC system that:
 - Supplies **100% fresh outdoor** air instead of stale recirculated air
 - Uses significantly **less energy** to operate than current recirculation systems
 - Can be installed on a **first cost** basis **equal to** or less than a standard mechanical system
 - Can be **retrofitted** to their existing systems (in most cases)
 - Is **user-friendly** for maintenance personnel to operate and maintain
- ⌚ If you could, you should...so let's see how....

Evaporative Cooling: Typical (Non-Evaporative) System



- Based on using **minimum** outside supply air, and recirculating a majority of the building return (exhaust) air

Evaporative Cooling: Typical (Non-Evaporative) System

Weaknesses of the Typical System:

- Recirculation causes internally generated contaminants to become concentrated and spread to all spaces served by the system
- Ventilation air is not managed properly
- The process is open loop on latent heat
- The scheme is predicated on using virgin energy to achieve psychrometric state point changes.
- The process is predicated on using energy intensive components

Evaporative Cooling:

What Does “Green” Mean To HVAC?

- ∴ “Green” is not installing a high efficiency boiler or alternative refrigerant chiller
- ∴ “Green” is avoiding the need for that boiler or chiller (or at least significantly downsizing them)
- ∴ “Green” is designing a high efficiency **hybrid system** that used high efficiency components

Evaporative Cooling:

"Green" Strategies For HVAC

- ⌚ **Dual Path Ventilation** - Separation of ventilation from heating and cooling processes permits elimination of terminal reheat and effective management of ventilation
- ⌚ **Energy Recovery** - Recycling heating/cooling energy permits ventilation air to be introduced into space at low thermodynamic cost
- ⌚ **Evaporative Cooling and Humidification** - Evaporative processes are the only processes which can close the loop on latent energy. They permit the avoidance of most cooling and humidification energy, and **are** applicable in **all** environments

Evaporative Cooling:

"Green" Strategies For HVAC

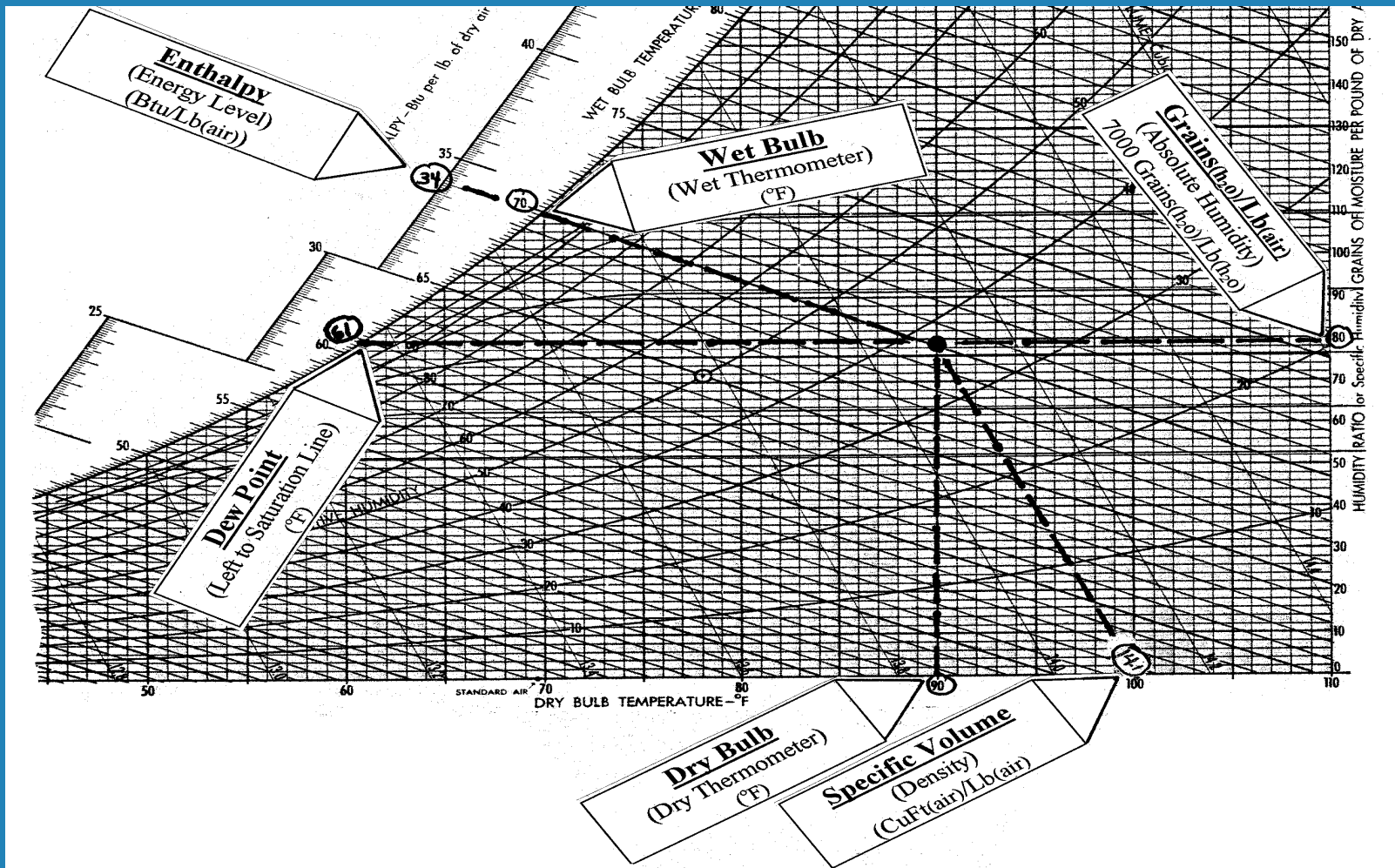
- o **Displacement Ventilation** - Permits small, 100% outside air systems to replace much larger systems and greatly reduce energy use
- o **Thermal Storage** - Properly employed, thermal storage can sharply reduce both the quantity and cost of heating and cooling energy use
- o **Process Synergism** - Synergism can be created between two processes to achieve more out of them than either process could provide alone

Evaporative Cooling:

"Green" Strategies For HVAC

- ⌚ **Multi-Functional Process Use** - Individual pieces of equipment can be used to serve multiple design objectives. This reduces the parasitic losses systems see from equipment not in use but which require energy to overcome.
- ⌚ **Amplification** - Multiple heat exchangers can be used to amplify cooling/heating energy for recovery while simultaneously eliminating the need for terminal reheat
- ⌚ **Avoidance** - Use of recoverable or "free" thermal resources before expending new energy resources

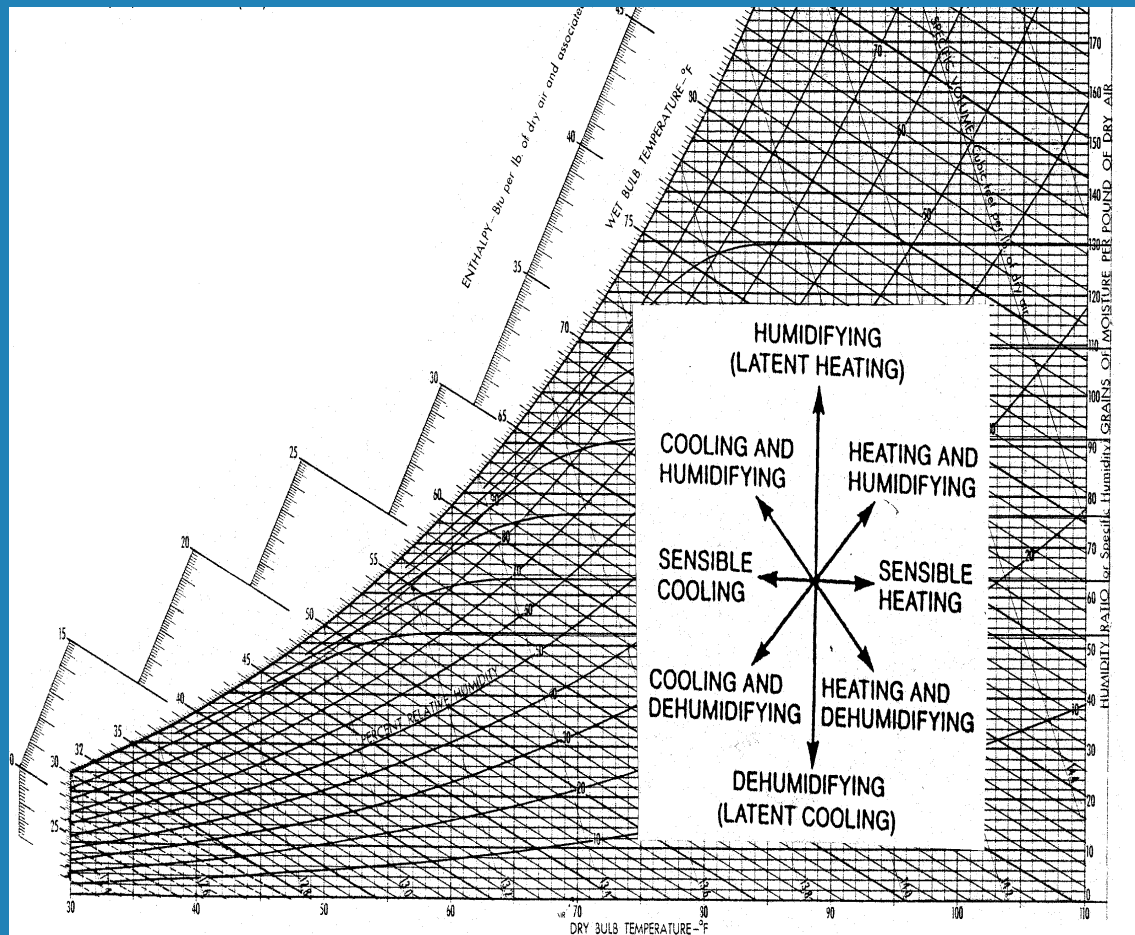
Evaporative Cooling: Understanding The Psychrometric Chart



Evaporative Cooling: Understanding The Psychrometric Chart

Ω All psychrometric processes can be seen as a combination of:

- Cooling
- Heating
- Humidifying
- Dehumidifying



Evaporative Cooling: Multiple Forms and Technologies

- ∞ Evaporative cooling technologies form the backbone of energy efficient hybrid HVAC systems
- ∞ There are 2 forms of evaporative cooling
 - **Direct**
 - Draws warm air through a wetted media
 - **Indirect**
 - Utilizes a heat exchanger to separate the supply air from the water used for evaporation
 - Uses a secondary air stream to reject heat from the evaporation process

Evaporative Cooling: Direct Evaporative Cooling Cycle

“Effectiveness” is defined by the following equation:

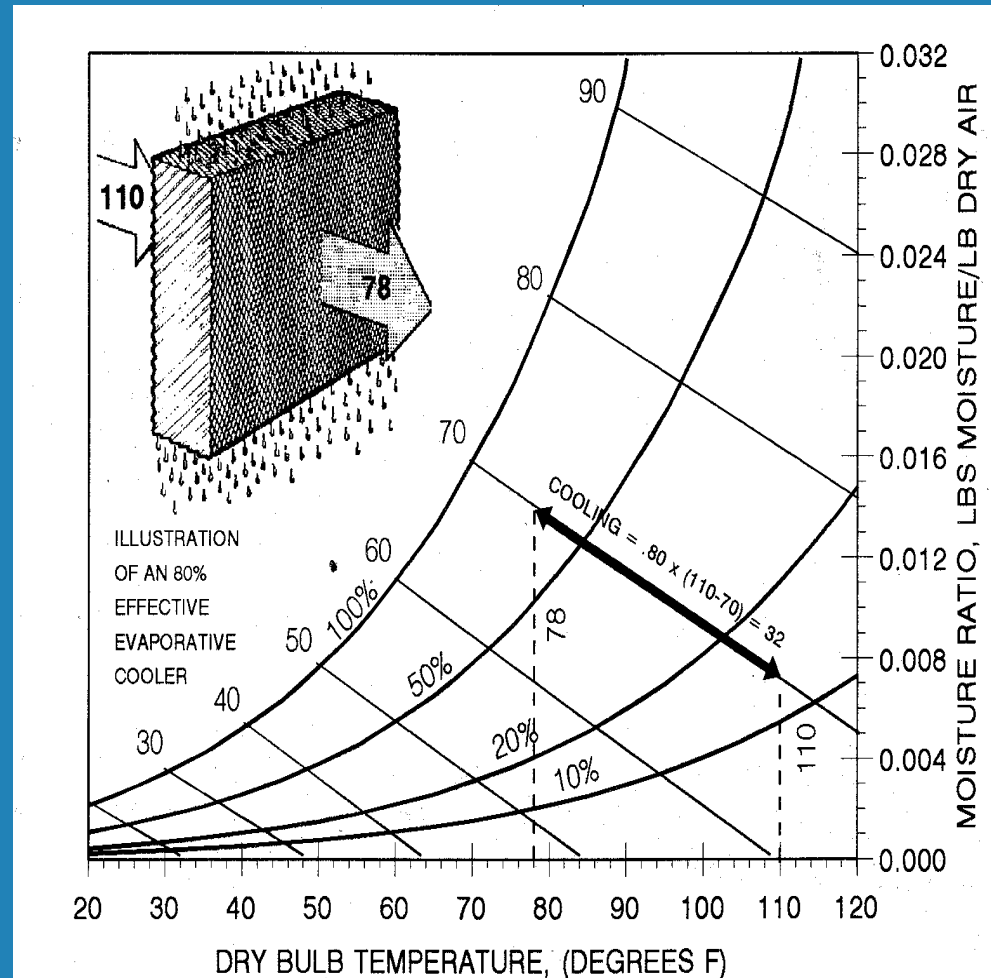
$$E = (T_{I_{db}} - T_{D_{db}}) \div (T_{I_{db}} - T_{I_{wb}})$$

“Discharge Temperature” can be determined by the following equation:

$$T_{D_{db}} = T_{I_{db}} - [E \times (T_{I_{db}} - T_{I_{wb}})]$$

Factors affecting effectiveness are:

- Type of Media
- Depth of Media
- Face Velocity



Evaporative Cooling: Indirect Evaporative Cooling Cycle

“Effectiveness” is defined by the following equation:

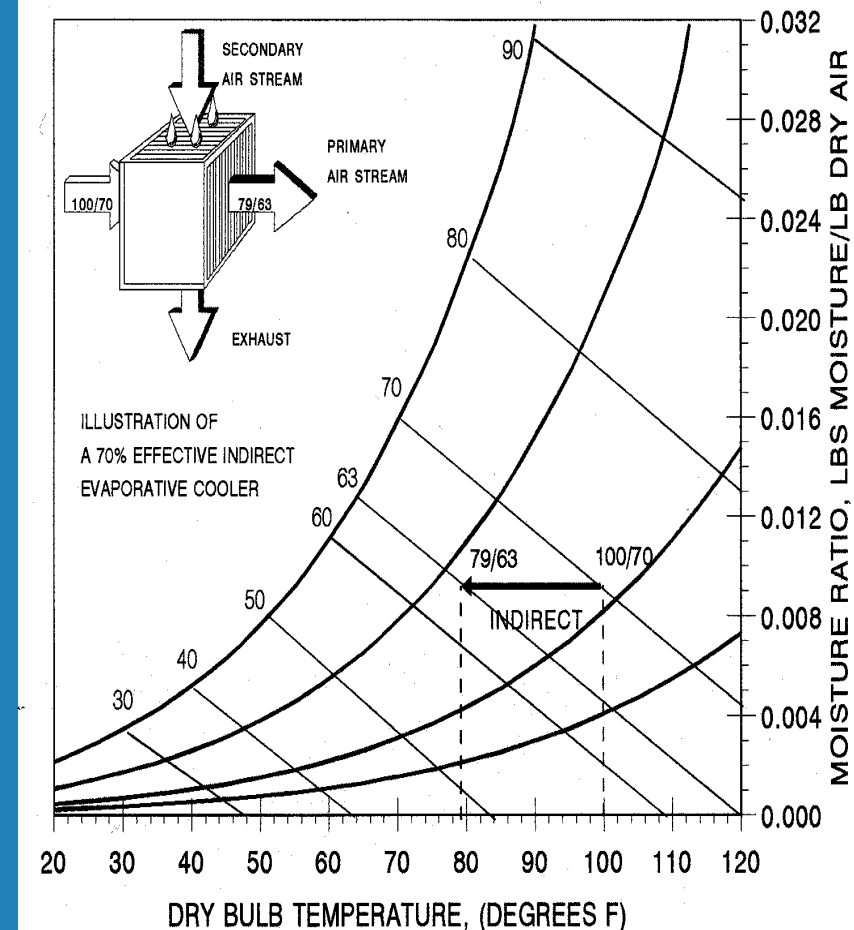
$$E = (T_{I_{db}} - T_{D_{db}}) \div (T_{I_{db}} - T_{I_{S_{wb}}})$$

“Discharge Temperature” can be determined by the following equation:

$$T_{D_{db}} = T_{I_{db}} - [E \times (T_{I_{db}} - T_{I_{S_{wb}}})]$$

Factors affecting effectiveness are:

- Type of Heat Exchanger
- Supply Air Flow Through Exchanger
- Secondary Air Flow
- Use of Outside Air vs. Building Exhaust as the Secondary Air Source



Evaporative Cooling:

Advantages of Indirect Cooling/Heating

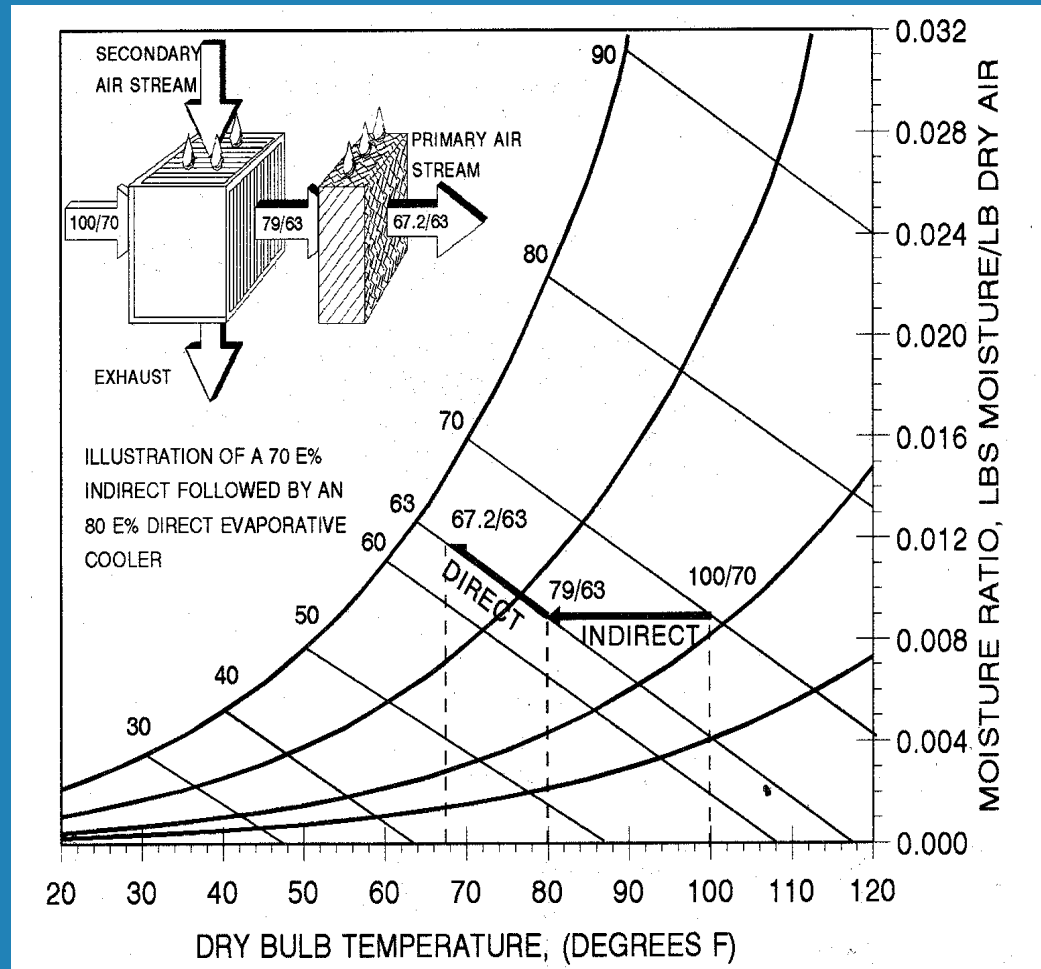
- ∩ Provides a sensible cooling process
- ∩ Extends the effective Economizer range
- ∩ Meets base cooling loads under part load conditions most of the time
- ∩ Can be used to provide winter energy (heat) recovery
- ∩ Makes 100% outside air applications more economical than recirculation systems
- ∩ Reduces need for refrigeration

Evaporative Cooling:

Indirect/Direct Evaporative Cooling Cycle

An Indirect / Direct combination will provide cooler air than either process by itself

In certain climates this combined process alone will provide true “comfort cooling”



Evaporative Cooling: Performance Chart (Low Wet Bulb Area)

SACRAMENTO, CALIFORNIA

Performance of Evaporative Cooling and Heat Recovery Technologies

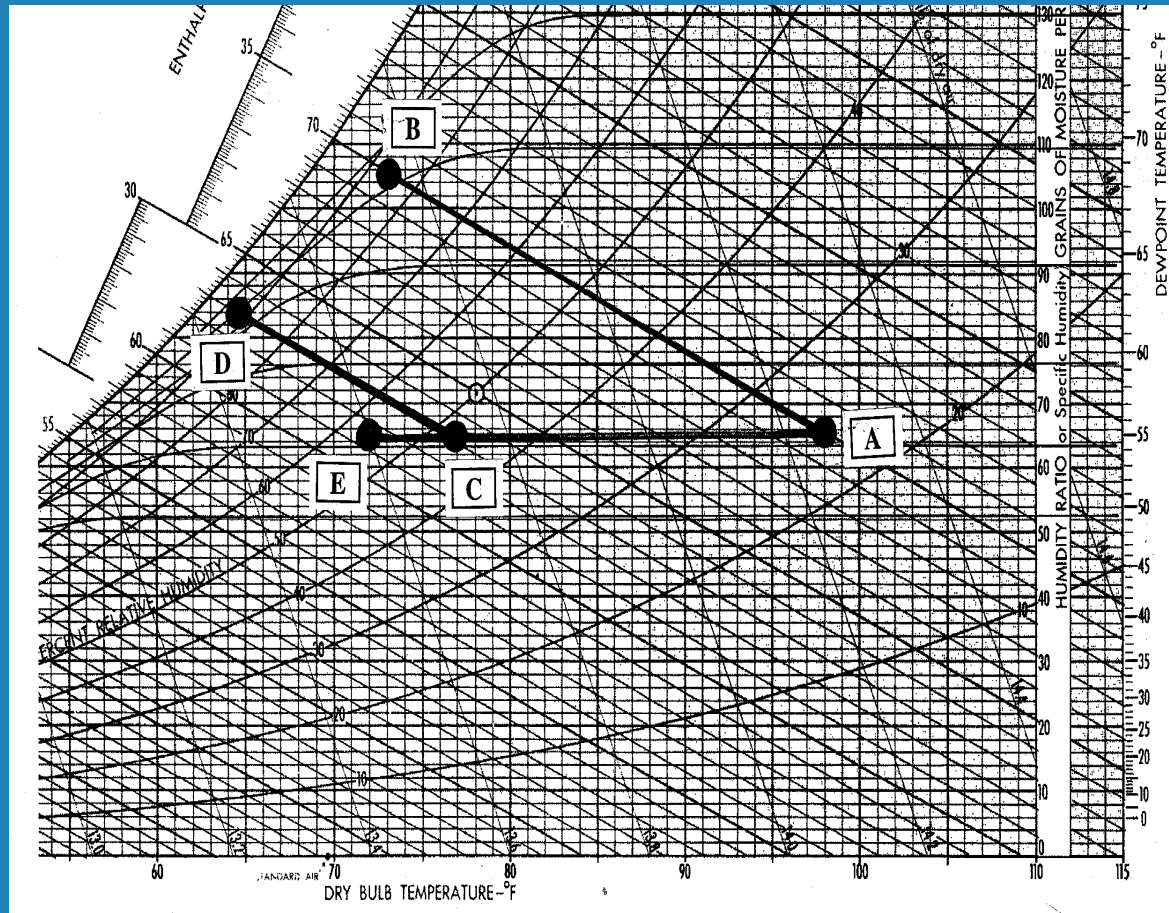
Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	INDIRECT Bldg. Exhaust as Secondary Air	DIRECT	INDIRECT DIRECT OSA as Secondary Air
107/70	7	79/61	74/59	74/70	63/61
102/70	59	78/63	73/61	73/70	65/63
97/68	144	75/61	72/60	71/68	62/61
92/66	242	72/60	70/59	69/66	61/60
87/65	301	70/59	69/59	67/65	60/59
82/63	397	68/58	68/58	65/63	59/58
77/61	497	65/57	66/57	63/61	58/57
72/59	641	62/55	65/56	60/59	56/55
67/57	821	60/54	64/56	58/57	55/54
62/54	1086	56/52	63/55	55/54	53/52

The above discharge temperatures (°F) are based on the following:

1. 75% Indirect Evaporative Effectiveness
2. 90% Direct Evaporative Effectiveness
3. 50% Heat Recovery Effectiveness
4. 75°F Building Exhaust Dry Bulb Temperature (Heat Recovery)
5. 63°F Building Exhaust Wet Bulb Temperature (Cooling)
6. DB = Dry Bulb Temperature
7. WB = Wet Bulb Temperature
8. OSA = Outside Air

Evaporative Cooling: Psychrometric Chart (Low Wet Bulb)

- ◊ Sacramento, CA
- ◊ A: Outside air
98/70
- ◊ B: Direct
73/70
- ◊ C: Indirect (OSA)
77/63
- ◊ D: Indirect/Direct
64.5/63
- ◊ E: Indirect (bldg.
exhaust)
72/62



Evaporative Cooling: Performance Chart (Low Wet Bulb Area)

RENO, NEVADA

Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	IND/DIRECT OSA as Secondary Air	DIRECT	HEAT RECOVERY
97/60	18	69/50	52/50	64/60	
92/60	127	68/51	53/51	63/60	
87/58	297	65/50	52/50	61/58	
82/56	339	63/49	59/49	59/56	
77/55	390	61/49	50/49	57/55	
72/53	397	58/48	49/48	55/53	
67/50	436	54/45	46/45	52/50	
62/48	720	52/44	45/44	49/48	68.5
57/46	783	49/43	44/43	47/46	66
52/43	871				63.5
47/40	922				61
42/36	714				58.5
37/33	873				56
32/29	762				53.5
27/25	550				51
22/21	310				48.5
17/16	246				46
12/11	74				43.5
7/6	10				41
2	2				38.5
-2	3				36.5
-7	6				34

Evaporative Cooling: Psychrometric Chart (Low Wet Bulb)

* **Reno, NV**

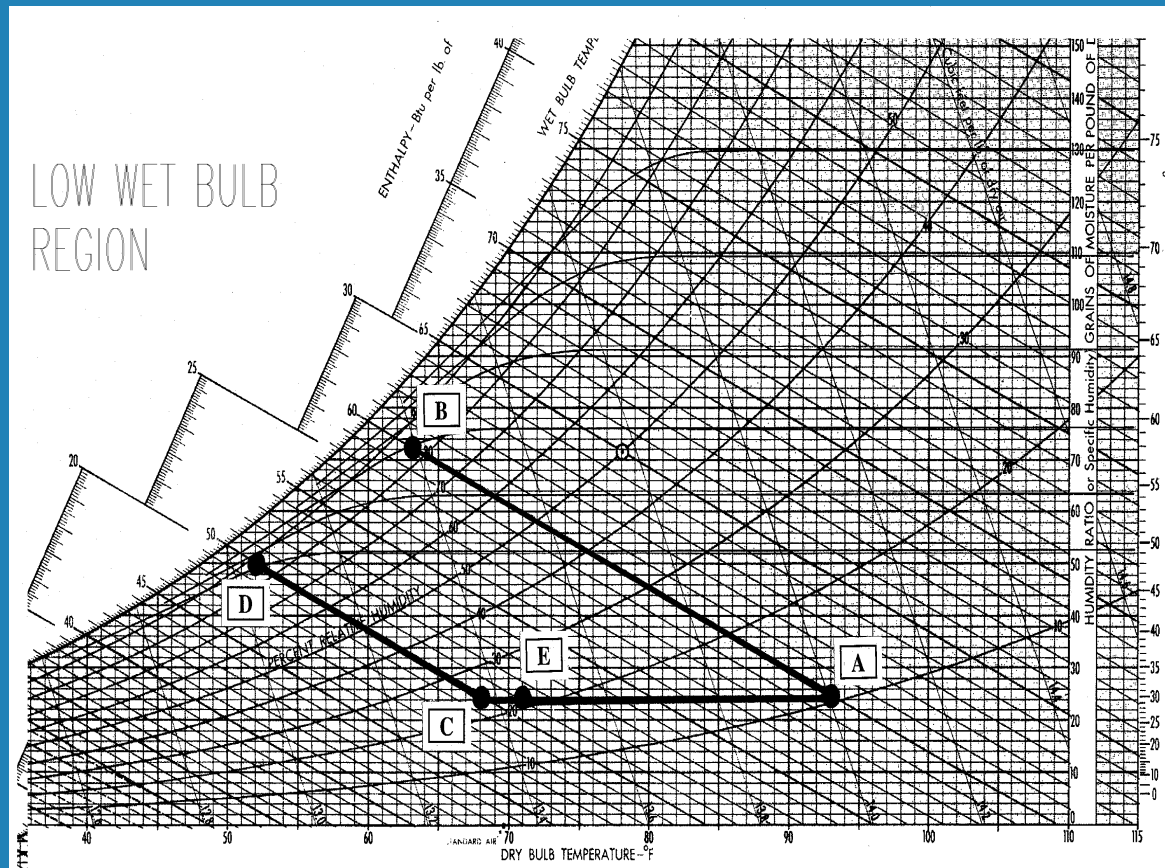
* **A:** Outside air
93/60

* **B:** Direct
63/60

* **C:** Indirect (OSA)
68/50

* **D:** Indirect/Direct
52/50

* **E:** Indirect (building
exhaust)
71/51



Evaporative Cooling: Performance Chart (High Wet Bulb Area)

CHICAGO, ILLINOIS

Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	INDIRECT Bldg. Exhaust as Secondary Air	DIRECT	INDIRECT DIRECT OSA as Secondary Air	HEAT RE- COVERY
97/76	6	81/71	71/69	78/76	72/71	
92/74	58	78/70	70/68	76/74	71/70	
87/72	165	76/69	69/67	73/72	70/69	
82/70	324	73/67	68/66	71/70	68/67	
77/67	487	70/65	67/64	68/67	66/65	
72/64	681	66/62	65/62	65/64	63/62	
67/61	759	62/59	64/60	62/61	60/58	
62/57	700	60/56		58/57	57/55	
57/52	604	53/50		53/52	51/49	
52/47	581					66
47/43	565					64
42/38	572					62
37/34	725					60
32/30	869					58
27/25	589					56
22/21	371					54
17/16	231					52
12/11	164					50
7/6	115					48
2/1	89					46
-3	53					44
-8	27					42
-13	11					40
-17	2					38

Psychrometric Chart (High Wet Bulb)

*Chicago, IL

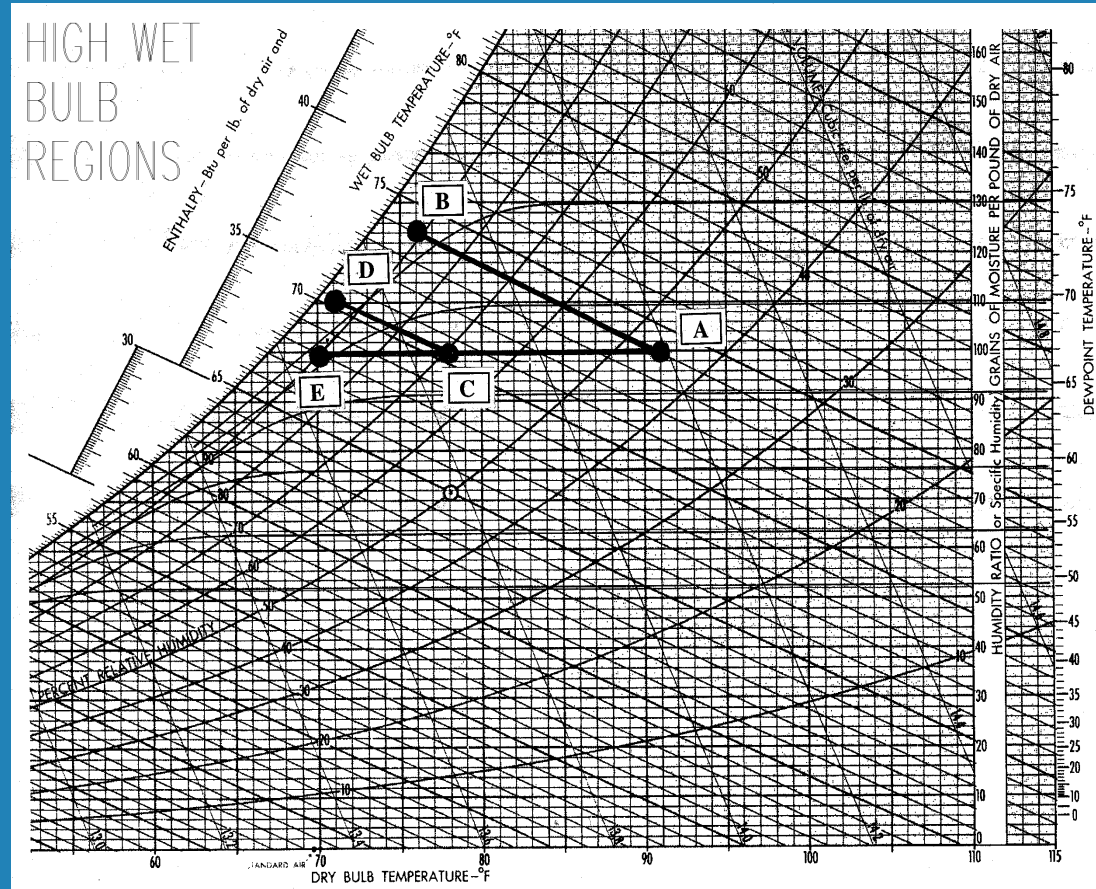
*A: Outside air
91/74

*B: Direct
76/74

*C: Indirect (OSA)
78/70

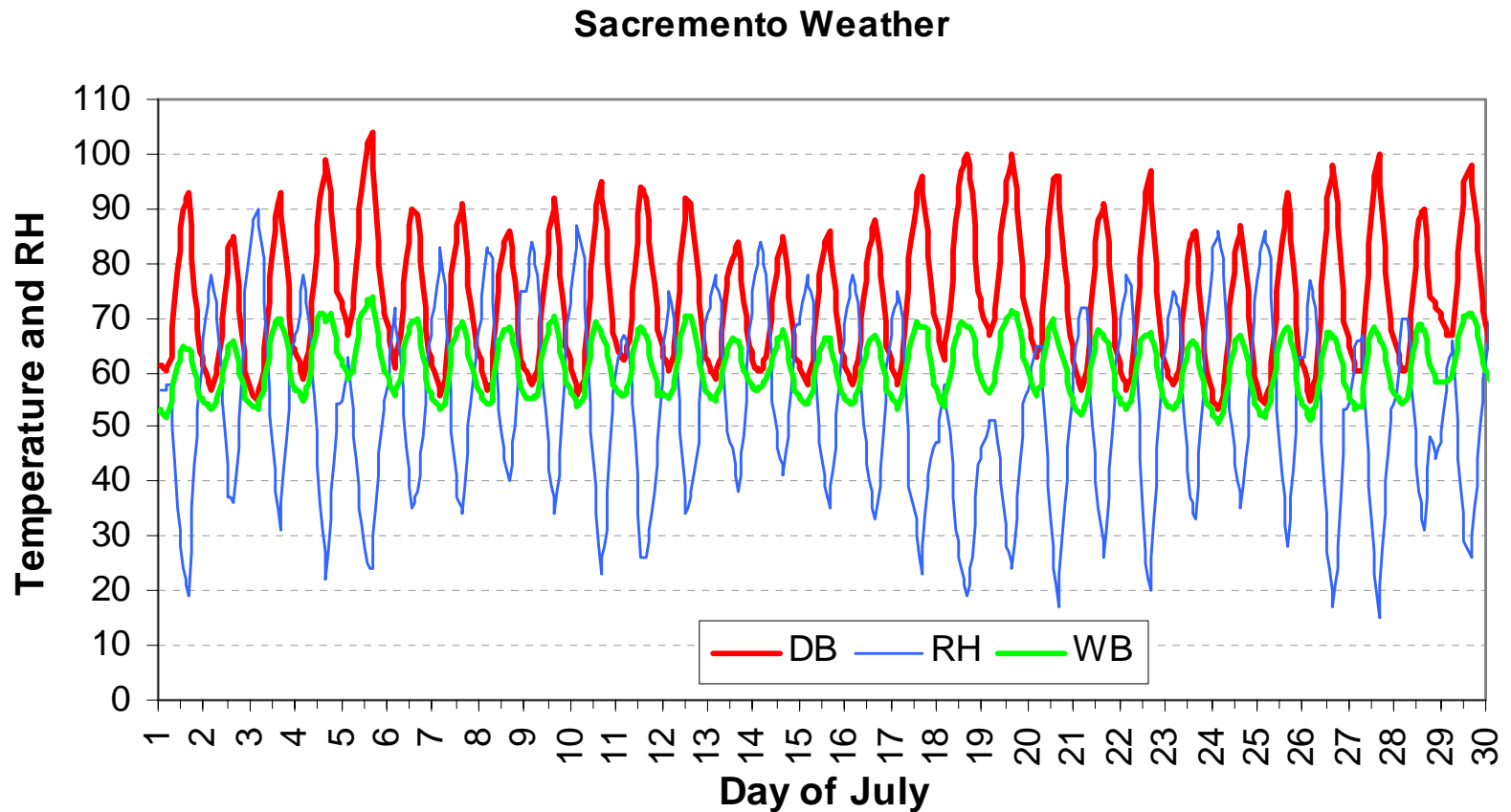
*D: Indirect/Direct
71/70

*E: Indirect (building exhaust)
70/68



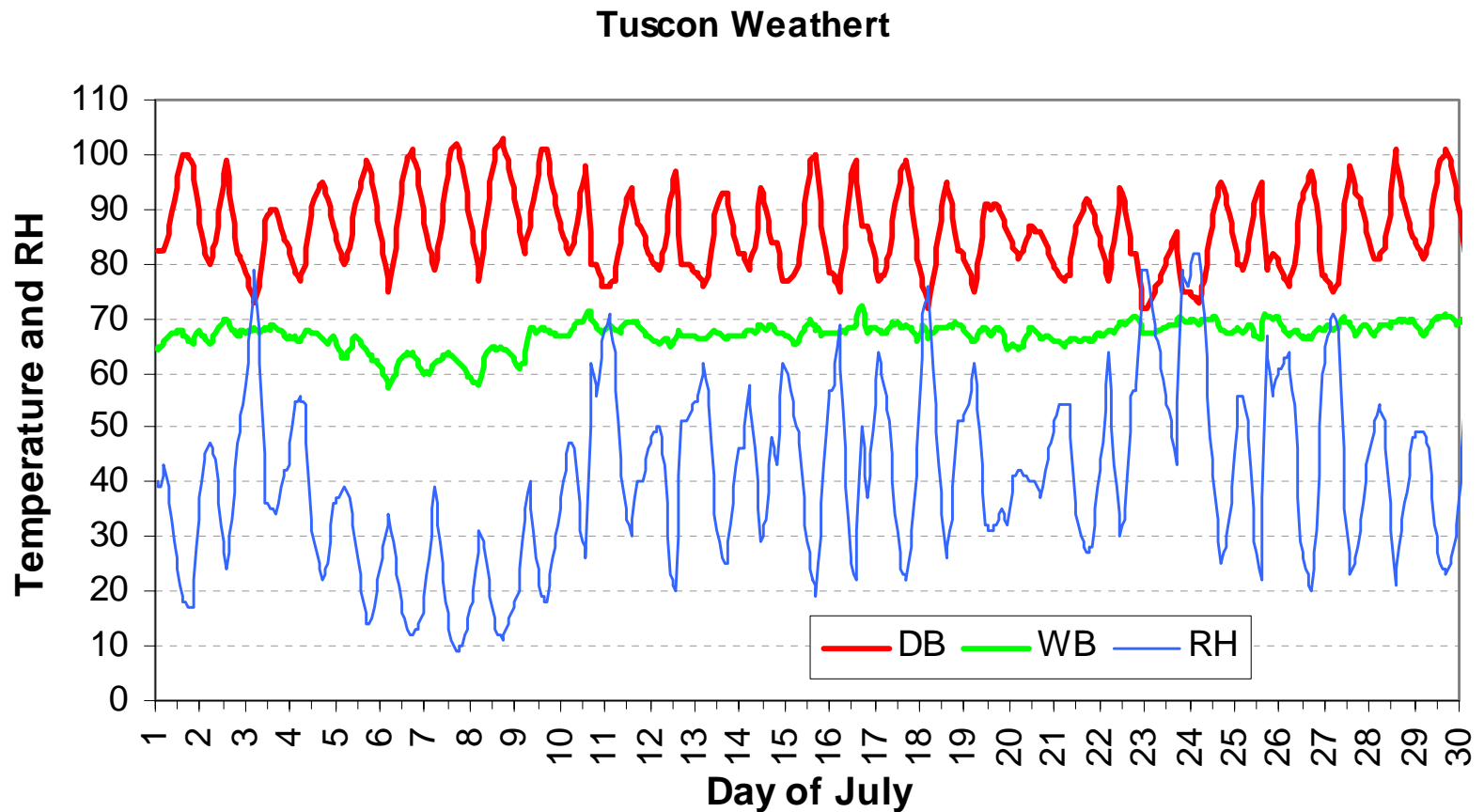
Evaporative Cooling:

Dry Bulb, Wet Bulb and Relative Humidity Excursions



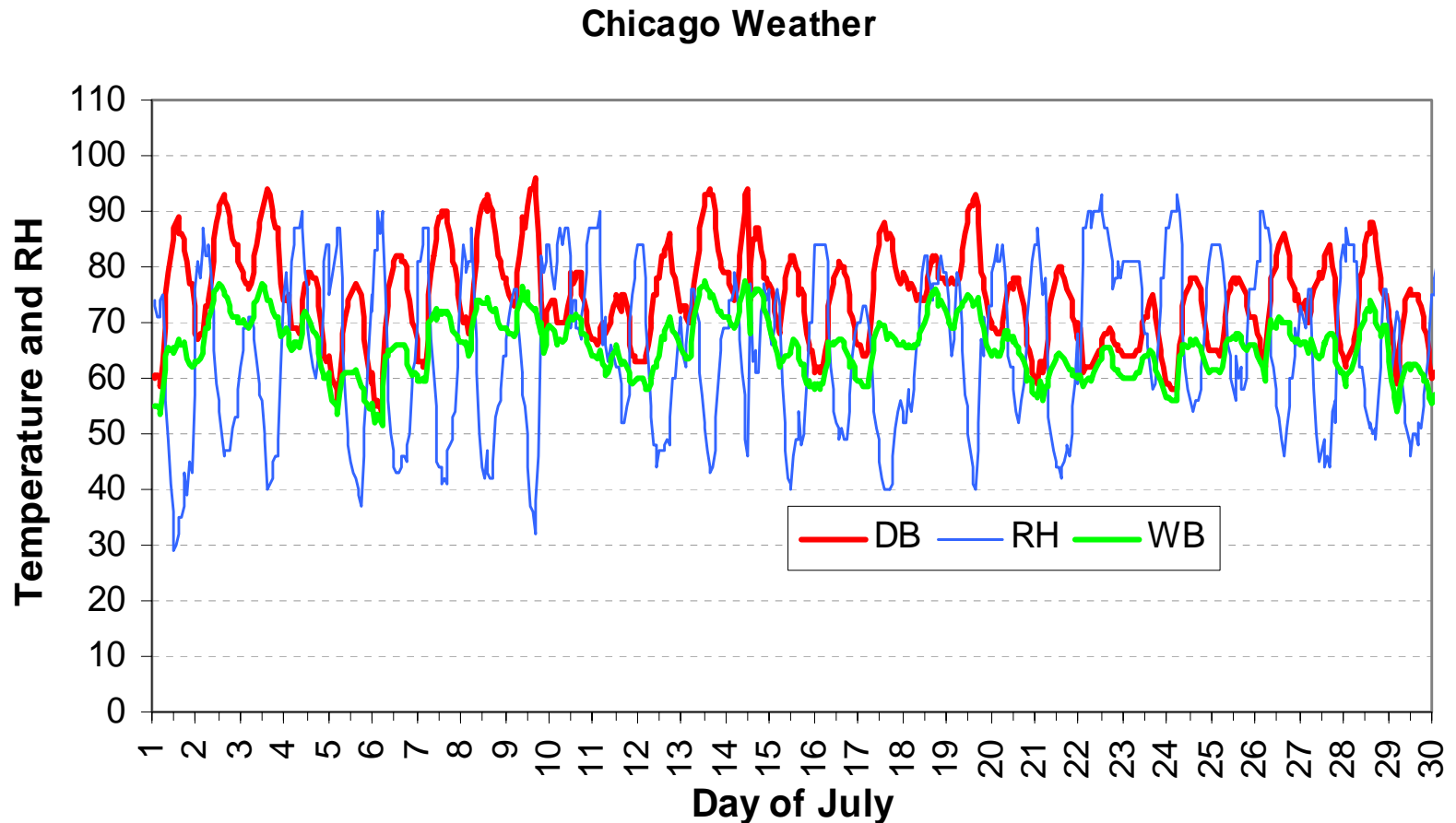
Evaporative Cooling:

Dry Bulb, Wet Bulb and Relative Humidity Excursions



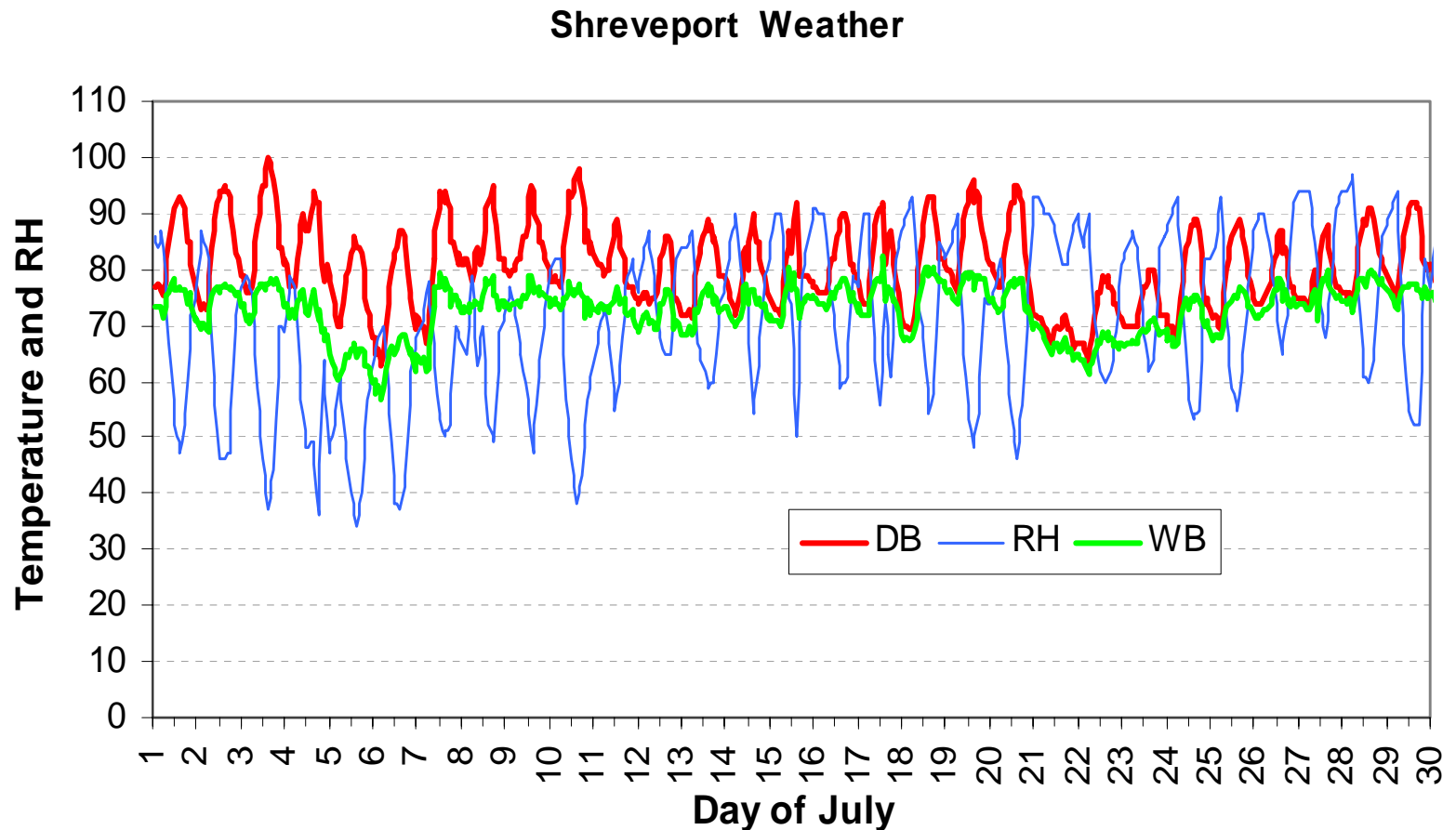
Evaporative Cooling:

Dry Bulb, Wet Bulb and Relative Humidity Excursions



Evaporative Cooling:

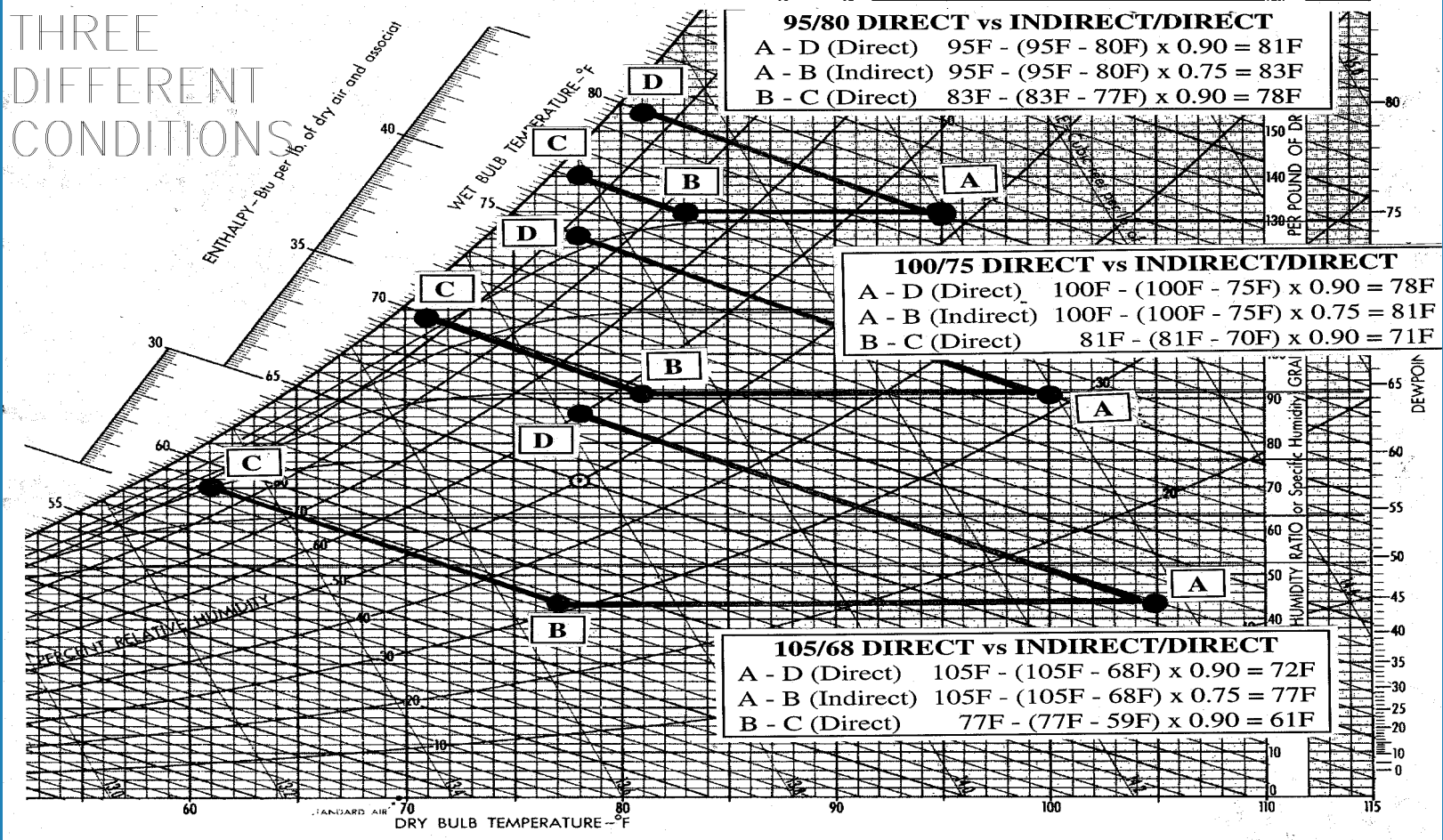
Dry Bulb, Wet Bulb and Relative Humidity Excursions



Evaporative Cooling:

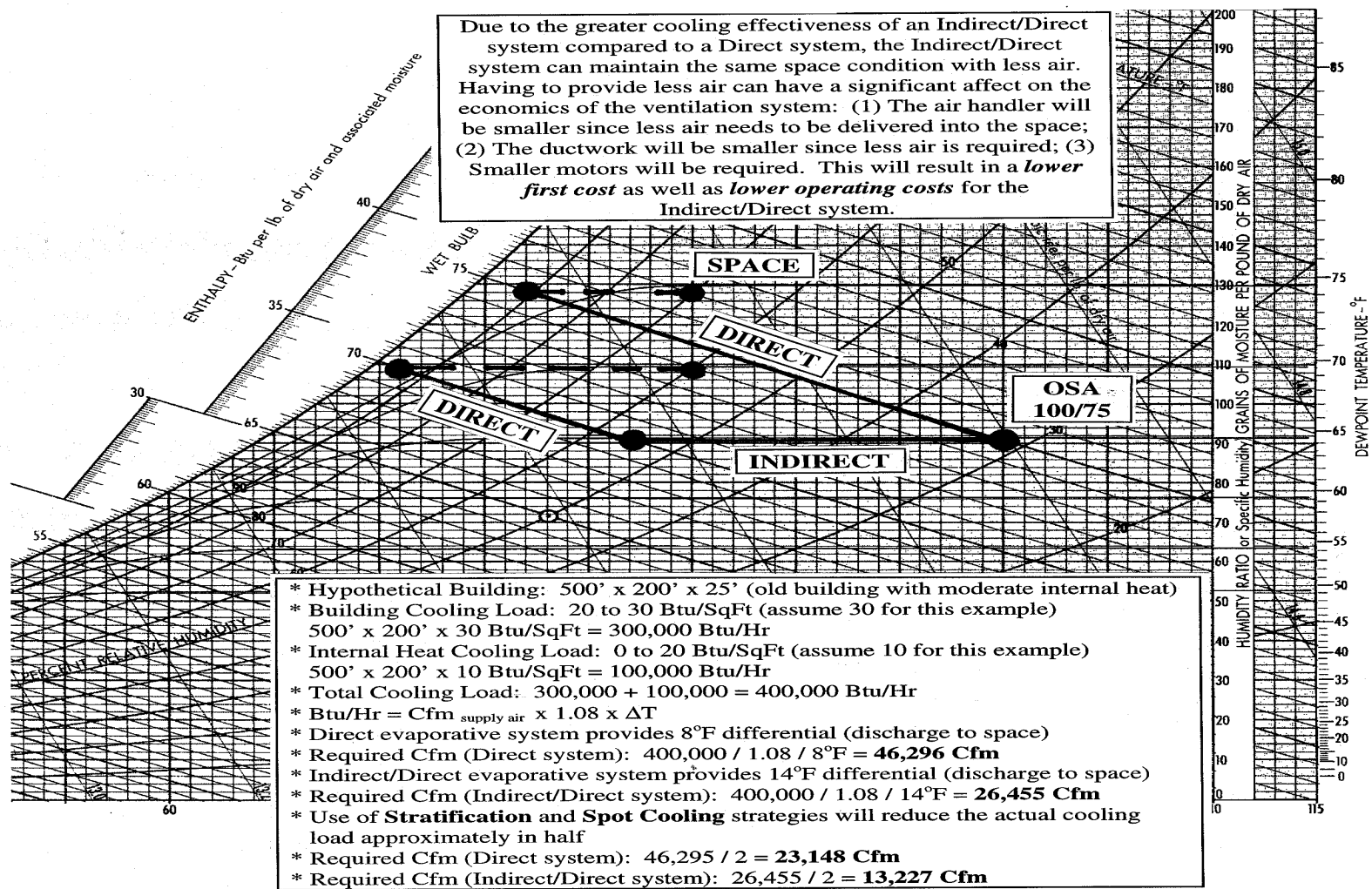
3 Different Outside Air Conditions

THREE
DIFFERENT
CONDITIONS



Evaporative Cooling:

Comparison of Direct vs Indirect/Direct



Evaporative Cooling: Typical Direct Evaporative Module

∞ Design Features of a Good Evaporative System

- Stainless Steel
- Bottom Drain
- Bleed and/or Purge
- Pre-filters
- Hood/Louvers
- Mist Eliminators
- Microbial Control
 - Dry the Pads
 - Run Fan After Pump Shuts Off
 - Flush Pads
 - Ozonation

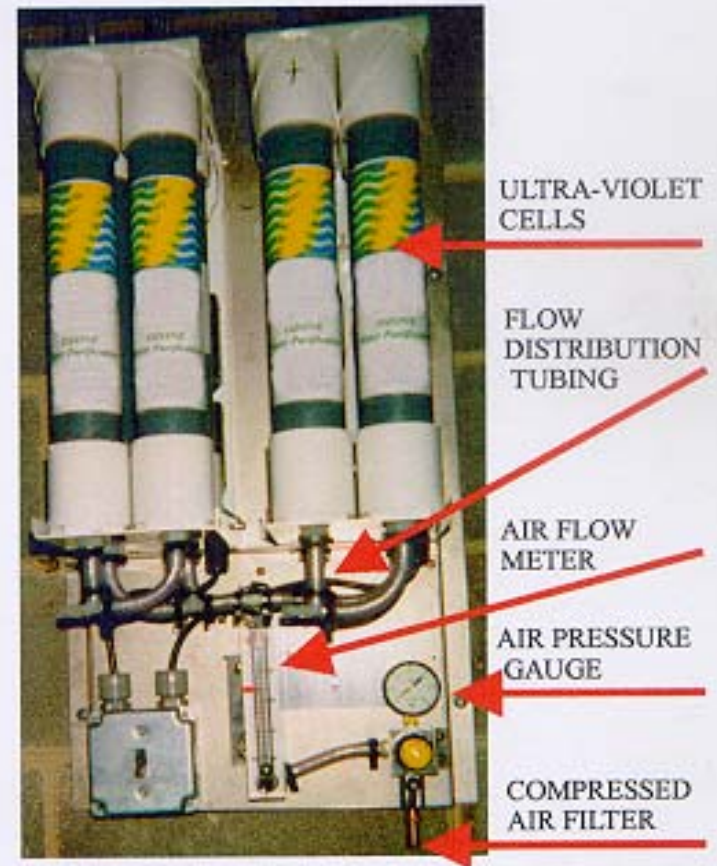
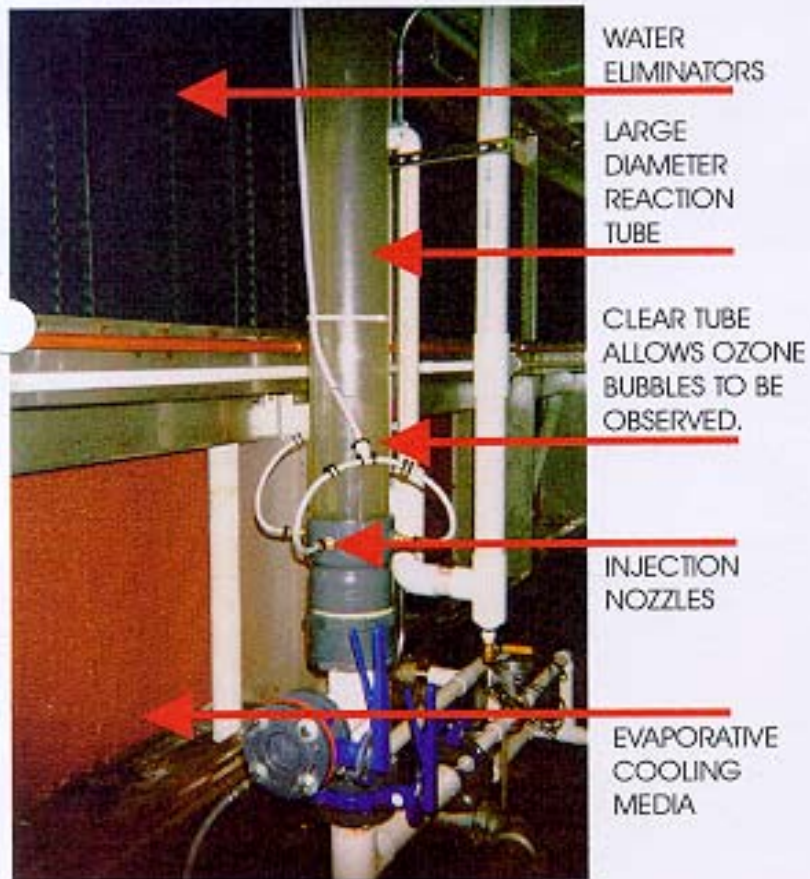


Evaporative Cooling

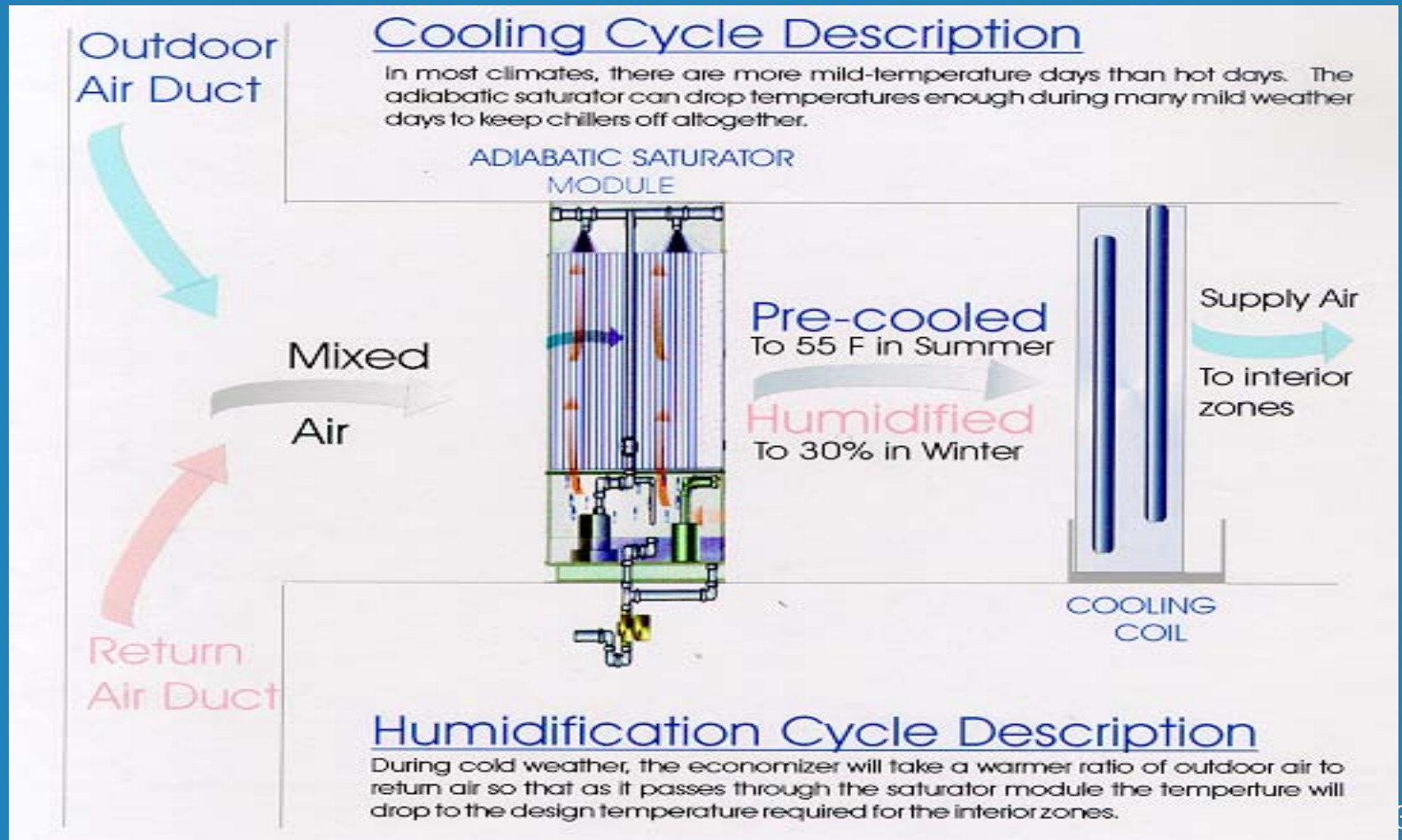
Microbial Control

- ∩ There have been no cases of Legionnaire's Disease associated with evaporative coolers (see ASHRAE Guideline 12-2000)
- ∩ There are significant differences between evaporative coolers and cooling towers
- ∩ The *Bio-Terminator*TM ozonation system was designed for active microbial control
- ∩ Ozone (O₃) is an extremely powerful oxidizer
 - Highly soluble in water
 - Very short half life
 - Benign at low levels

Evaporative Cooling: Microbial Control



Evaporative Cooling: Cooling And Humidification



Evaporative Cooling:

What Are The Adverse Affects Of Heat?

- ∩ Industrial facilities are particularly susceptible to problems related to heat during extended periods of the year.
 - Heat stress
 - Increased down time
 - Quality control problems
 - Reduced productivity
- ∩ Many companies have done internal studies on the true costs of such heat related problems...the results are discouraging and most often not made public!

Evaporative Cooling:

What Are The Adverse Affects Of Heat?

NASA Report CR-1205-1 (Heat Stress)

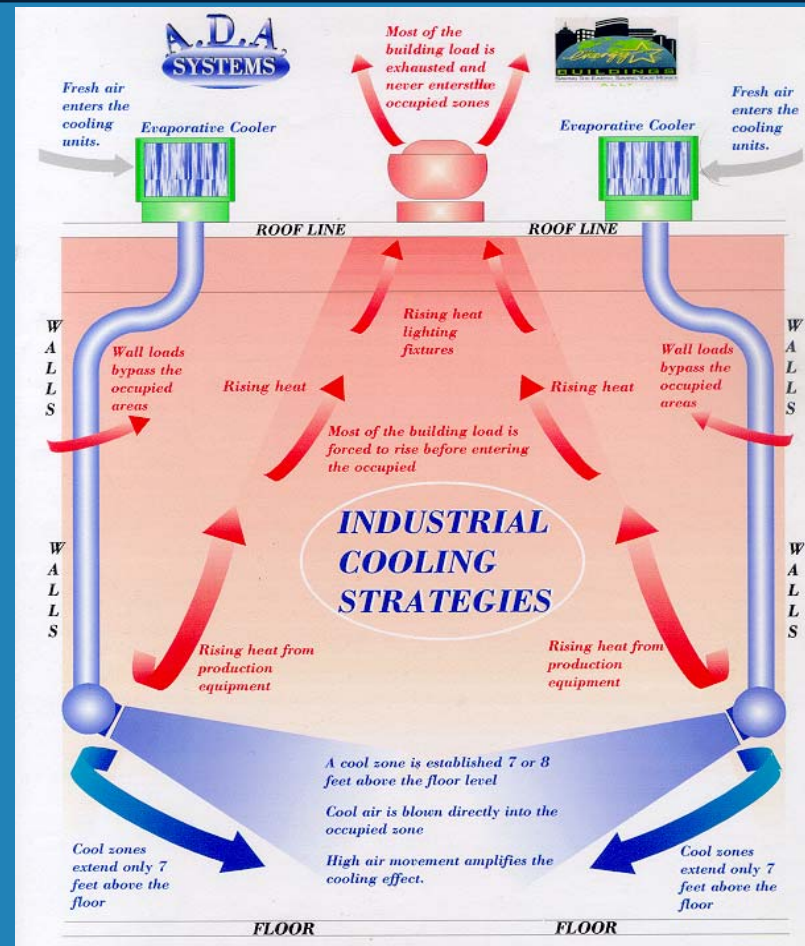
Effective Temperature	75	80	85	90	95	100	105
Loss in Work Output	3%	8%	18%	29%	45%	62%	79%
Loss in Accuracy	-	5%	40%	300%	700%	-	-

- ∩ ACGIH has established guidelines for reducing heat stress, including:
- Increased rates of ventilation
 - Evaporative cooling of ventilation air
 - Displacement ventilation with stratification
 - Increased fluid intake

Evaporative Cooling: Industrial Cooling Strategies

∞ Strategies to increase the effectiveness of evaporative cooling:

- Displacement Ventilation
- Stratification
- Spot Cooling
- Adjustable Diffusers



Evaporative Cooling: Indirect/Direct Case Study No. 1

CLIENT: Indianapolis Wood Veneer Manufacturer

PROBLEM: Ovens Produce Over 100°F Conditions

GOAL: Low Cost Relief Cooling

SOLUTION:

- * Indirect/ Direct Cooling System
- * Stratification Strategy
- * Spot Cooling
- * Eliminates The Previously Proposed 1,880-Ton Chilled Water System**



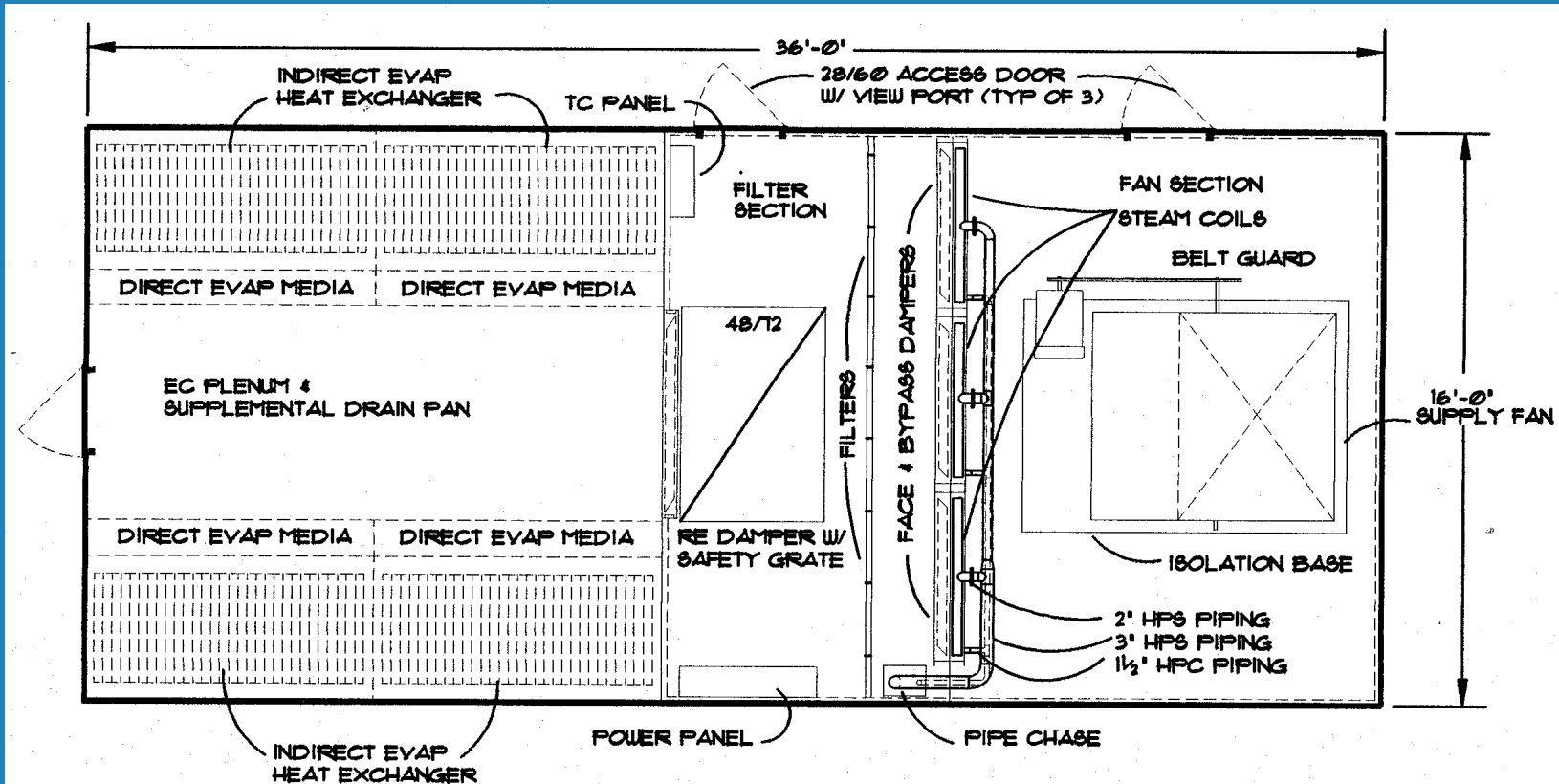
Evaporative Cooling: Indirect/Direct Case Study No. 1

EQUIPMENT SCHEDULE

Mark	Manu- facturer	Supply Cfm	E.A.T (O.S.A) (°FDB)	E.A.T (O.S.A) (°FWB)	L.A.T. Indirect (°FDB)	L.A.T. Indirect (°FWB)	L.A.T. Direct (°FDB)	Efficiency (Indirect) (%)	Efficiency (Direct) (%)
AHU-1		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-2		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-3		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-4		25,000	91.0	75.0	78.0	71.5	72.2	80	90

Evaporative Cooling: Indirect/Direct Case Study No. 1

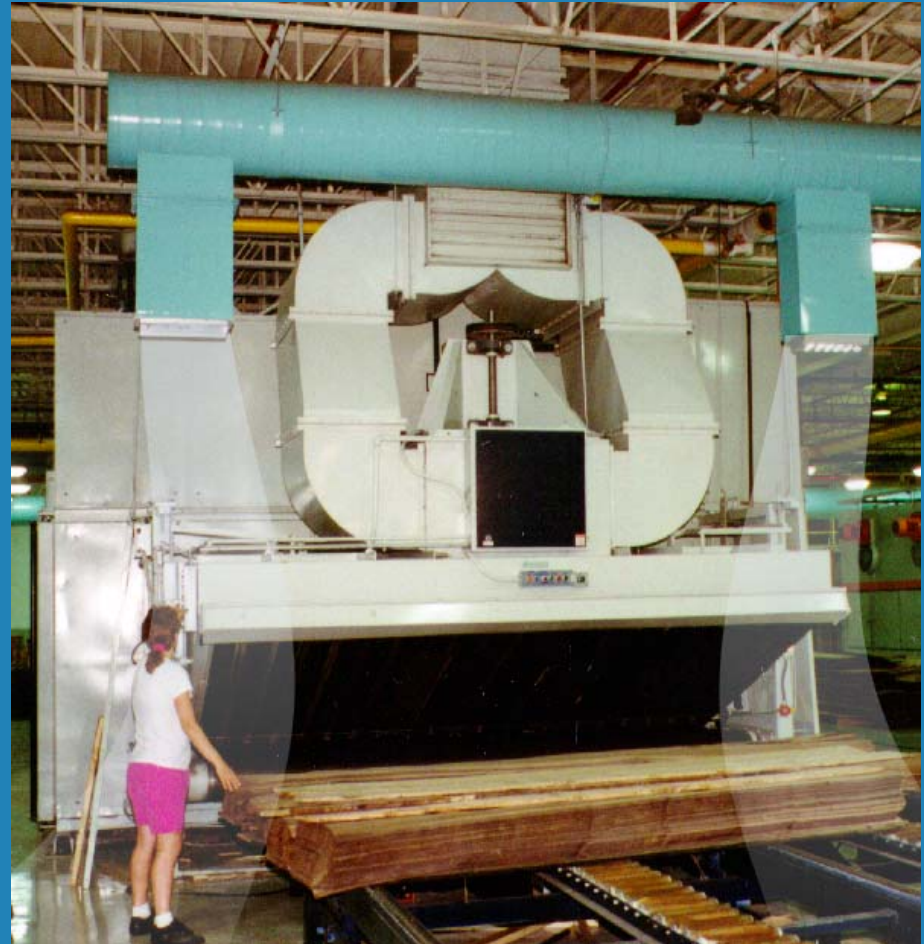
62,000 CFM Make Up Air Handling Unit



Evaporative Cooling: Indirect/Direct Case Study No. 1

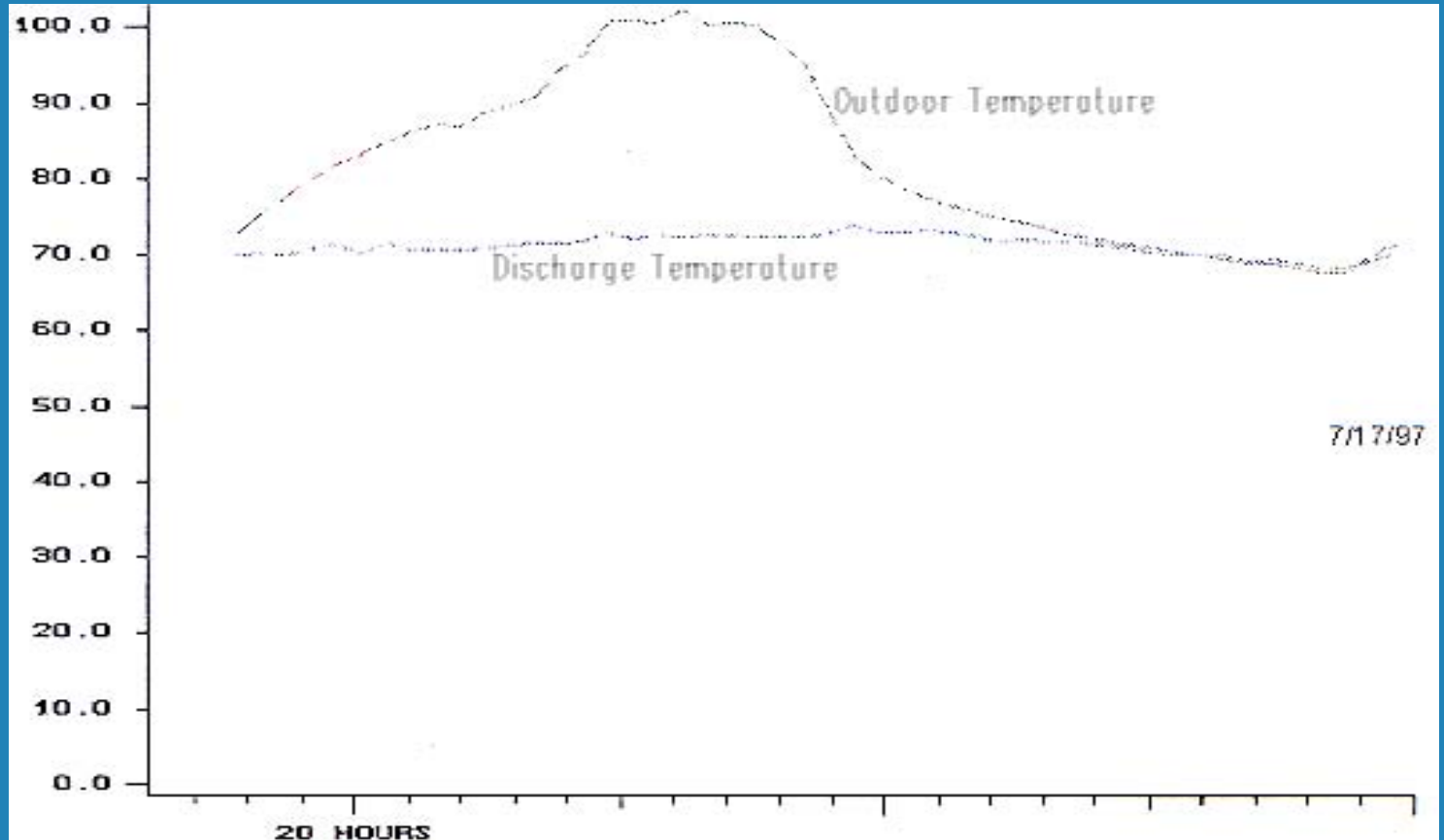
SPOT COOLING

- * Adjustable Diffusers
- * High Air Movement
- * Establishes Cool Zone



Evaporative Cooling: Indirect/Direct Case Study No. 1

Field Temperature Recording



Evaporative Cooling:

Indirect With Chiller & Heat Recovery

- ⌚ An Indirect evaporative pre-cooler can be used to reduce the size of a new chilled water system, or can be used to reduce the outside air load on an existing system.
- ⌚ When used for energy (heat) recovery in winter operations, that same indirect unit can pre-heat the outside air.
 - In certain parts of the country, the energy savings from heat recovery may be even greater than those from evaporative cooling

Evaporative Cooling: Indirect Case Study No. 2

- ❧ CLIENT: Midwest Printing Facility
- ❧ PROBLEM: Inability Of Chilled Water System To Maintain Space Conditions
- ❧ GOAL: Avoid Increasing The Chilled Water Plant

*SOLUTION:

- *Indirect Precooling
- *Eliminates The Need To Double The Size Of The Chilled Water System
- *Regains The Desired Space Conditions



Evaporative Cooling: Indirect Case Study No. 2

*BEFORE: 18,000 CFM Outside
Air Hood



*AFTER: 18,000 CFM Indirect
Evaporative Pre-Cooler



Evaporative Cooling:

Indirect With Chiller & Heat Recovery

Case Study No. 3

- ∩ CLIENT: Midwest Automotive Facility
- ∩ GOAL: Achieve **LEED**TM Certification In An Industrial Facility
- ∩ PROBLEM: How To Achieve Meaningful Energy Cost Reductions And Still Maintain Good IAQ/IEQ
- ∩ SOLUTION: Indirect Evaporative Pre-Cooling and Pre-Heating
 - Reduces Chilled Water Plant By ~42%
 - Reduces Heating Plant By ~60%

Evaporative Cooling: Indirect With Chiller & Heat Recovery (30% Outdoor Air Unit) (Industrial Facility)

IDEC COOLING PERFORMANCE (24-7 operating hours)

JOB: *****- **Lansing, MI**

THIRTY (30) - 30% OUTDOOR AIR UNITS

LOCATION

EER SEASONAL AVERAGE

SUPPLY AIR TEMP

EXHAUST

HOURS OF COOLING OPERATION

IDEC SIZE

IDEC PRIMARY and SECONDARY CFM

IDEC ENERGY DRAW (kW/hr) - ON

IDEC ENERGY DRAW (watts/hr) - OFF

IDEC EQUIPMENT COST (uninstalled)

IDEC EQUIPMENT COST (uninstalled)

IDEC EQUIPMENT COST (per ton uninstalled)

Water Chiller/cooling tower/pumps/piping (uninstalled)

Premium for IDEC equipment over chilled water equipment

IDEC TONS delivered at design conditions

CHILLER TONS required at design conditions

TOTAL COOLING TONS (IDEC + Chiller)

IDEC Efficiency

Kw/hr Cost

Water Cost (per 1000 gallons)

IDEC Yearly energy costs

CHILLER equivalent yearly energy costs

YEARLY COOLING SEASON SAVINGS

(ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500)

LANSING MI

41.6 Btu/watt Ent Halpy

57.7 56.5 24.7

59.7 57.5

3180

16 Linear Ft 2,470

15,000 Each

4,940 watts 308.73 4,940

2,470 watts 102.91 watts/ft of module

\$ 33,750 per air handling unit

\$ 2.25 per CFM

\$ 974 per ton cooling

\$ 700 per ton cooling

\$ 9,500 per air handling unit

35 Tons Also Tons of Chiller size reduction

48 Tons

83 Tons dedicated to OA load

80% efficiency

\$ 0.08 Kw/hr

\$ 2.50 per 1000 gallons

\$ 1,576 per air handling unit

\$ 6,555 per air handling unit

\$ **5,000** per air handling unit

***30% Outdoor Air Unit**

PRIMARY			SECONDARY			PRIMARY			IDEC	IDEC	IDEC	EER	HRS	ENERGY	ENERGY	EER	ENERGY	COST	GALS	COST	OPER-
DB	WB	H	DB	WB	H	DB	WB	H	Btu/ Lb	Out Btu/hr	Input Watts/ Hr	Btu Per Watt	Total Yearly	Output for each BIN	BIN% of Total Output	Contri- bution /BIN	Input for Each /BIN	Energy Input IDEC	Water Consum- ption	Water Consum- ption	ATING Cost TOTAL
(F)	(F)	Btu/lb	(F)	(F)	Btu/lb	(F)	(F)	Btu/lb	Drop	Drop		Watt	BIN	BIN	Output	/BIN	/BIN				
97	76	39.38	75	64	29.30	70.6	68.0	33.22	6.2	4.2E+05	4,939.7	84	6	2.5E+06	1%	1	3.0E+04	\$ 2	375	\$ 1	\$ 3
92	74	37.50	75	64	29.30	69.6	67.5	32.81	4.7	3.2E+05	4,939.7	64	58	1.8E+07	6%	4	2.9E+05	\$ 23	3,375	\$ 8	\$ 31
87	72	35.71	75	64	29.30	68.6	66.5	31.99	3.71975	2.5E+05	4,939.7	51	165	4.1E+07	14%	7	8.2E+05	\$ 65	7,875	\$ 20	\$ 85
82	70	33.99	75	64	29.30	67.6	65.0	30.80	3.2	2.2E+05	4,939.7	44	324	7.0E+07	24%	10	1.6E+06	\$ 128	12,000	\$ 30	\$ 158
77	67	31.54	75	64	29.30	66.6	63.2	29.42	2.1	1.4E+05	4,939.7	29	487	7.0E+07	24%	7	2.4E+06	\$ 192	13,500	\$ 34	\$ 226
72	64	29.25	75	64	29.30	65.6	61.8	28.38	0.9	5.9E+04	4,939.7	12	681	4.0E+07	14%	2	3.4E+06	\$ 269	12,000	\$ 30	\$ 299
67	61	27.11	67	61	29.30	62.2	59.2	26.55	0.6	3.8E+04	4,939.7	8	759	2.9E+07	10%	1	3.7E+06	\$ 300	8,625	\$ 22	\$ 321
62	57	24.44	62	57	29.30	58.0	55.2	23.91	0.5	3.6E+04	4,939.7	7	700	2.5E+07	8%	1	3.5E+06	\$ 277	6,075	\$ 15	\$ 292
												42	3180	3.0E+08	100%	32	1.6E+07	\$ 1,257	63,825	\$ 160	\$ 1,416

Evaporative Cooling:

Indirect With Chiller & Heat Recovery

(30% Outdoor Air Unit) (Industrial Facility)

IDEC HEATING PERFORMANCE (24/7 operating hours)

JOB: *****- **Lansing, MI**

THIRTY(30) - 30% OUTDOOR AIR UNITS

LOCATION LANSING
TOTAL HOURS OPERATION (24 hour /7 day) 5568
IDEC SIZE 16 FT
IDEC PRIMARY and SECONDARY CFM 15,000 Each
IDEC ENERGY DRAW (Kw/hr) - pumps off 4,940
IDEC EQUIPMENT COST (per CFM) \$ 2.25
IDEC EFFICIENCY (dry) 65%
Kw/hr Cost \$ 0.08
NatGas (per Therm) \$ 0.75
Assumed Furnace Efficiency 100%
YEARLY HEATING SEASON SAVINGS \$ 12,700

(ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500)

SUMMARY

Yearly Heating Savings	\$ 12,700
Yearly Cooling Savings	\$ 5,000
TOTAL Yearly Savings	\$ 17,700
IDEC Premium	\$ 9,500
PAYBACK - Years	0.54

***30% Outdoor Air Unit**

SUPPLY AIR ENTERING (F)	EXHAUST AIR ENTERING (F)	HOURS PER YEAR (Hrs)	SUPPLY AIR LEAVING (F)	EXHAUST AIR LEAVING (F)	BTU/HR RECOVERED (Btu/hr)	BTU/BIN RECOVERED (Btu/bin)	THERMS PER BIN /Furn Eff	SAVINGS PER BIN	PARA- SIDICAL LOSS (Kw)	PARA- SIDICAL LOSS (\$)	NET SAV- INGS (\$)
57	70	604	65	62	1.4E+05	8.31E+07	831	\$ 623	2,984	\$ 239	\$ 384
52	70	581	64	58	1.9E+05	1.11E+08	1,106	\$ 830	2,870	\$ 230	\$ 600
47	70	565	62	55	2.4E+05	1.37E+08	1,375	\$ 1,031	2,791	\$ 223	\$ 808
42	70	572	60	52	3.0E+05	1.69E+08	1,694	\$ 1,271	2,825	\$ 226	\$ 1,045
37	70	725	58	49	3.5E+05	2.53E+08	2,531	\$ 1,898	3,581	\$ 287	\$ 1,612
32	70	869	57	45	4.0E+05	3.49E+08	3,493	\$ 2,620	4,293	\$ 343	\$ 2,277
27	70	589	55	42	4.5E+05	2.68E+08	2,679	\$ 2,009	2,909	\$ 233	\$ 1,777
22	70	371	53	39	5.1E+05	1.88E+08	1,884	\$ 1,413	1,833	\$ 147	\$ 1,266
17	70	231	51	36	5.6E+05	1.30E+08	1,295	\$ 971	1,141	\$ 91	\$ 880
12	70	164	50	32	6.1E+05	1.01E+08	1,006	\$ 755	810	\$ 65	\$ 690
7	70	115	48	34	6.7E+05	7.67E+07	767	\$ 576	568	\$ 45	\$ 530
2	70	89	43	34	6.7E+05	5.94E+07	594	\$ 445	440	\$ 35	\$ 410
-3	70	53	38	34	6.7E+05	3.54E+07	354	\$ 265	262	\$ 21	\$ 244
-8	70	27	33	34	6.7E+05	1.80E+07	180	\$ 135	133	\$ 11	\$ 124
-13	70	11	28	34	6.7E+05	7.34E+06	73	\$ 55	54	\$ 4	\$ 51
-17	70	2	24	34	6.7E+05	1.33E+06	13	\$ 10	10	\$ 1	\$ 9

Evaporative Cooling: Indirect With Chiller & Heat Recovery (100% Outdoor Air Unit) (Industrial Facility)

IDEC COOLING PERFORMANCE (24-7 operating hours)

JOB: ***** - **Lansing, MI**

SEVEN(7) - ALL OUTDOOR AIR UNITS

LOCATION

EER SEASONAL AVERAGE

SUPPLY AIR TEMP

EXHAUST

HOURS OF COOLING OPERATION

IDEC SIZE

IDEC PRIMARY and SECONDARY CFM

IDEC ENERGY DRAW (kW/hr) - ON

IDEC ENERGY DRAW (watts/hr) - OFF

IDEC EQUIPMENT COST (uninstalled)

IDEC EQUIPMENT COST (uninstalled)

IDEC EQUIPMENT COST (per ton uninstalled)

Water Chiller/cooling tower/pumps/piping (uninstalled)

Premium for IDEC equipment over chilled water equipment

IDEC TONS delivered at design conditions

CHILLER TONS required at design conditions

TOTAL COOLING TONS (IDEC + Chiller)

IDEC Efficiency

Kw/hr Cost

Water Cost (per 1000 gallons)

IDEC Yearly energy costs

CHILLER equivalent yearly energy costs

YEARLY COOLING SEASON SAVINGS

LANSING

discharge

44.9 Btu/watt Enthalpy

62 61.0 27.3

70 57.5

3180

48 Linear Ft 2,470

50,000 Each

14,819 watts 308.73 1481899%

7,409 watts 102.91 watts/ft of module

\$ 112,500 per air handling unit

\$ 2.25 per CFM

\$ 1,158 per ton cooling

\$ 700 per ton cooling

\$ 44,500 per air handling unit

97 Tons Also Tons of Chiller size reduction

129 Tons

227 Tons

80% efficiency

\$ 0.08 Kw/hr

\$ 2.50 per 1000 gallons

\$ 4,834 per air handling unit

\$ 21,722 per air handling unit

\$ **16,900** per air handling unit

***100% Outdoor Air Unit**

PRIMARY Air Entering			SECONDARY Air entering			PRIMARY Air leaving			IDEC	IDEC	IDEC	EER	HRS	ENERGY	ENERGY	EER	ENERGY	COST	GALS	COST	OPER-	
DB	WB	H	DB	WB	H	DB	WB	H	Btu/ Lb	Out Btu/hr	Input Watts/ Hr	Btu Per Watt	Total Yearly BIN	Output for each BIN	BIN% of Total Output	Contri- bution /BIN	Input for Each /BIN	Energy Input IDEC	Water Consump- tion	Water Consump- tion	ATING Cost TOTAL	
(F)	(F)	Btu/lb	(F)	(F)	Btu/lb	(F)	(F)	Btu/lb	Drop	Drop												
97	76	39.38	75	66	30.65	72.2	68.5	34.20	5.2	1.2E+06	14,819.0	79	6	7.0E+06	1%	1	8.9E+04	\$ 7	1,250	\$ 3	\$ 10	
92	74	37.50	75	66	30.65	71.2	68.0	32.20	5.3	1.2E+06	14,819.0	80	58	6.9E+07	8%	6	8.6E+05	\$ 69	11,250	\$ 28	\$ 97	
87	72	35.71	75	66	30.65	70.2	67.0	31.60	4.11	9.2E+05	14,819.0	62	165	1.5E+08	17%	11	2.4E+06	\$ 196	26,250	\$ 66	\$ 261	
82	70	33.99	75	66	30.65	69.2	65.5	30.80	3.2	7.2E+05	14,819.0	48	324	2.3E+08	26%	12	4.8E+06	\$ 384	40,000	\$ 100	\$ 484	
77	67	31.54	75	66	30.65	68.2	63.7	29.62	1.9	4.3E+05	14,819.0	29	487	2.1E+08	23%	7	7.2E+06	\$ 577	45,000	\$ 113	\$ 690	
72	64	29.25	75	66	30.65	67.2	62.3	28.58	0.7	1.5E+05	14,819.0	10	681	1.0E+08	11%	1	1.0E+07	\$ 807	40,000	\$ 100	\$ 907	
67	61	27.11	67	61	30.65	62.2	59.7	26.76	0.3	7.9E+04	14,819.0	5	759	6.0E+07	7%	0	1.1E+07	\$ 900	28,750	\$ 72	4/972	
62	57	24.44	62	57	30.65	58.0	55.7	24.01	0.4	9.7E+04	14,819.0	7	700	6.8E+07	8%	0	1.0E+07	\$ 830	20,250	\$ 51	\$ 880	
													45	3180	9.0E+08	100%	39	4.7E+07	\$ 3,770	212,750	\$ 532	\$ 4,300

Evaporative Cooling: Indirect With Chiller & Heat Recovery (100% Outdoor Air Unit) (Industrial Facility)

IDEC HEATING PERFORMANCE (24/7 operating hours)

JOB: *****- **Lansing, MI**

SEVEN(7) - ALL OUTDOOR AIR UNITS

LOCATION	LANSING
TOTAL HOURS OPERATION (24 hour /7 day)	5568
IDEC SIZE	48 Ft
IDEC PRIMARY and SECONDARY CFM	50,000 Each
IDEC ENERGY DRAW (Kw/hr) - pumps off	14,819.0
IDEC EQUIPMENT COST (per CFM)	\$ 2.25
IDEC EFFICIENCY (dry)	65%
Kw/hr Cost	\$ 0.08
NatGas (per Therm)	\$ 0.75
Assumed Furnace Efficiency	100%
YEARLY HEATING SEASON SAVINGS	\$ 43,100

(ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500)

SUMMARY

Yearly Heating Savings	\$ 43,100
Yearly Cooling Savings	\$ 16,900
TOTAL Yearly Savings	\$ 60,000
IDEC Premium	\$ 44,500
PAYBACK - Years	0.74

*100% Outdoor Air Unit

SUPPLY AIR ENTERING (F)	EXHAUST AIR ENTERING (F)	HOURS PER YEAR (Hrs)	SUPPLY AIR LEAVING (F)	EXHAUST AIR LEAVING (F)	BTU/HR RECOV- ERED (Btu/hr)	BTU/BIN RECOV- ERED (Btu/bin)	THERMS PER BIN /Furn Eff	SAVINGS PER BIN	PARA- SIDICAL LOSS (Kw)	PARA- SIDICAL LOSS (\$)	NET SAV- INGS (\$)
57	70	604	65	62	4.6E+05	2.77E+08	2,769	\$ 2,077	8,951	\$ 716	\$ 1,361
52	70	581	64	58	6.3E+05	3.69E+08	3,688	\$ 2,766	8,610	\$ 689	\$ 2,077
47	70	565	62	55	8.1E+05	4.58E+08	4,582	\$ 3,437	8,373	\$ 670	\$ 2,767
42	70	572	60	52	9.9E+05	5.65E+08	5,648	\$ 4,236	8,476	\$ 678	\$ 3,558
37	70	725	58	49	1.2E+06	8.44E+08	8,437	\$ 6,327	10,744	\$ 860	\$ 5,468
32	70	869	57	45	1.3E+06	1.16E+09	11,644	\$ 8,733	12,878	\$ 1,030	\$ 7,703
27	70	589	55	42	1.5E+06	8.93E+08	8,931	\$ 6,698	8,728	\$ 698	\$ 6,000
22	70	371	53	39	1.7E+06	6.28E+08	6,280	\$ 4,710	5,498	\$ 440	\$ 4,270
17	70	231	51	36	1.9E+06	4.32E+08	4,317	\$ 3,238	3,423	\$ 274	\$ 2,964
12	70	164	50	32	2.0E+06	3.35E+08	3,354	\$ 2,516	2,430	\$ 194	\$ 2,321
7	70	115	48	34	2.2E+06	2.56E+08	2,558	\$ 1,918	1,704	\$ 136	\$ 1,782
2	70	89	43	34	2.2E+06	1.98E+08	1,980	\$ 1,485	1,319	\$ 106	\$ 1,379
-3	70	53	38	34	2.2E+06	1.18E+08	1,179	\$ 884	785	\$ 63	\$ 821
-8	70	27	33	34	2.2E+06	6.01E+07	601	\$ 450	400	\$ 32	\$ 418
-13	70	11	28	34	2.2E+06	2.45E+07	245	\$ 184	163	\$ 13	\$ 170
-17	70	2	24	34	2.2E+06	4.45E+06	44	\$ 33	30	\$ 2	\$ 31

Evaporative Cooling: Indirect With Typical Rooftop Unit Case Study No. 4

- ∞ Industrial facility with high outside air requirements (100% OSA for cooling and 80% OSA for heating)
- Standard rooftop mechanical units
 - Indirect evaporative precoolers
 - DX tonnage reduced by 50%
 - Heat recovery in winter operation



Evaporative Cooling: Turbine Power Boost

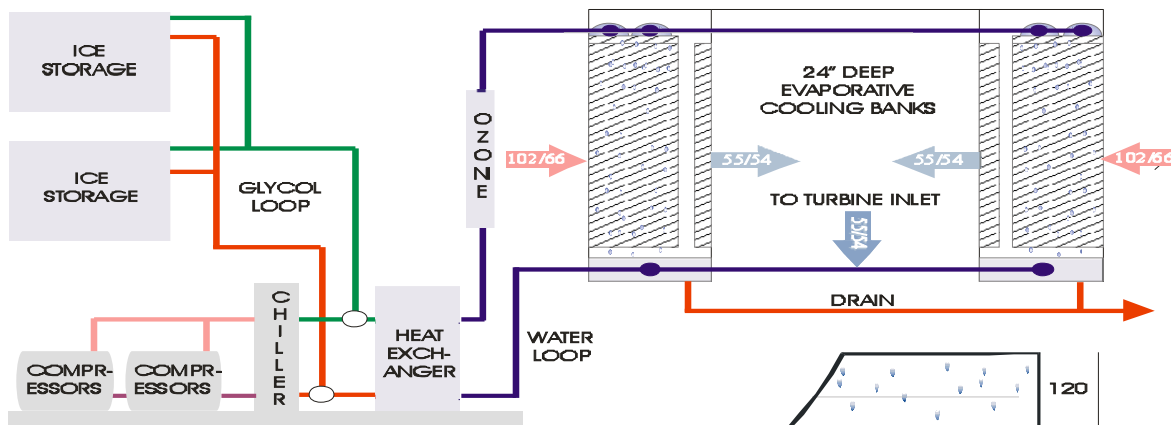
TURBINE POWER BOOSTER PACKAGE

EVAPORATIVE COOLING - ICE STORAGE - CHILLER

GENERAL DESCRIPTION: The most efficient means of boosting turbine peak power and efficiency is a hybrid system that synergistically combines the best of several technologies

ICE STORAGE: Peak power demand lasts about 5 hours a day. With ice storage, the chillers can spend 19 hours making ice, thus reducing the chiller plant to about one sixth the normal size.

EVAPORATIVE COOLING MEDIA: 24" deep evaporative media banks have replaced chilled water coils to increase cooling output and reduce the required ton-hours of the chiller /ice storage system. On a Las Vegas design day, the evaporative cooling effect does 30% of the work. During less severe weather, it can handle 100% of the load.



OUTPUT CALCULATIONS:

Load: $200,000 \text{ Cfm} \times (30.8 - 17.8) \times 4.5 / 12,000 = 950 \text{ Tons}$

Evap. Cooling: $200,000 \times (67 - 55) \times 1.08 = 225 \text{ Tons}$

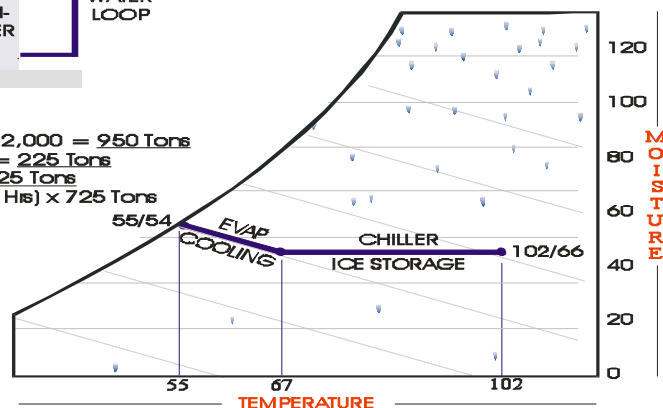
Adjusted Load: $950 \text{ Tons} - 225 \text{ Tons} = 725 \text{ Tons}$

Ice Storage Reduces Tonnage: $(5 \text{ hrs} / 24 \text{ Hrs}) \times 725 \text{ Tons}$

Chiller Size = 150 Tons

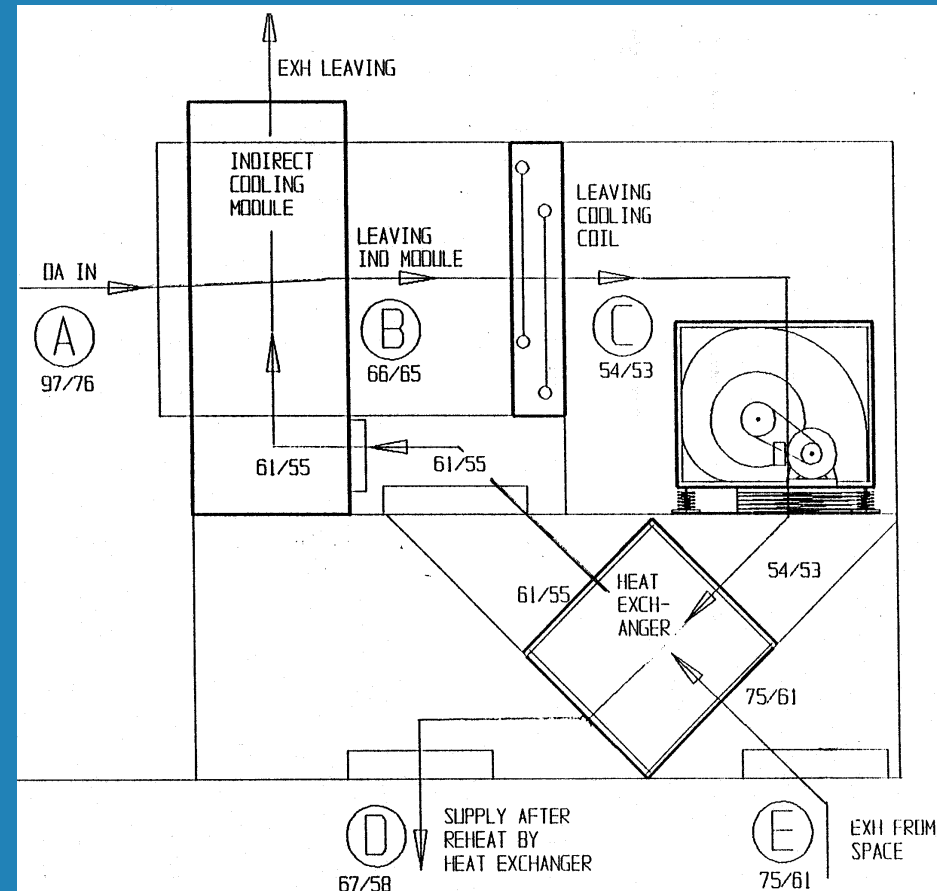
ADA SYSTEMS

425 North Gary Avenue
Carol Stream, Illinois 60188
Phone: 630-871-2500
Fax: 630-871-2585
E-mail: davek@interaccess.com

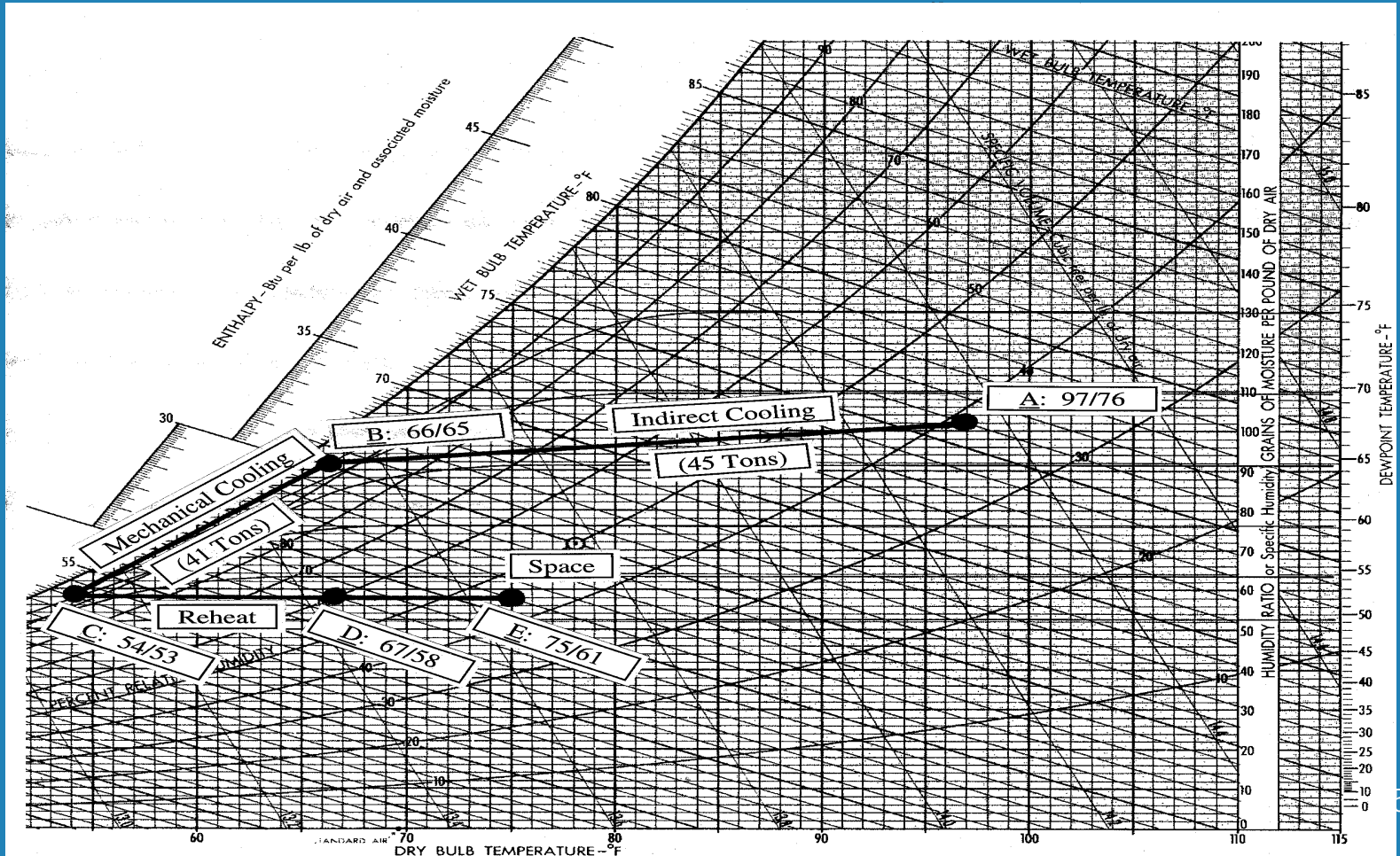


Evaporative Cooling: Indirect/Mechanical (Low Energy Reheat)

- Facilities with high OSA needs often require expensive reheat
- Components of a low energy reheat system:
 - Indirect evaporative pre-cooler
 - Mechanical cooling coil
 - Secondary heat exchanger



Evaporative Cooling: Indirect/Mechanical (Low Energy Reheat)



Evaporative Cooling: Hybrid (Multi-Functional) System

- ∞ Wausau West High School, Wausau, WI
- ∞ Problems they were facing:
 - Expensive retrofit of existing chiller plant
 - Severe indoor air quality
 - Non-compliance with Standard 62




Evaporative Cooling: Hybrid (Multi-Functional) System

∞ The **Regenerative Double Duct™** is a hybrid, multi-component/function design that is proving to be one of the most energy efficient HVAC systems available. Its major components are:

- **Indirect Evaporative Cooler (IDEC)**
 - First stage cooling
 - First stage heating
 - Limited capacity to act as a cooling tower
- **Direct Evaporative Cooler (DEC)**
 - Direct evaporative cooling (when conditions permit)
 - Air filtration/scrubbing
 - Humidification

Evaporative Cooling: Hybrid (Multi-Functional) System

- **Secondary Plate-And-Frame Heat Exchanger (HX)**
 - Provides heating for the hot deck
 - Sub-cools building exhaust
- **Thermal Energy Storage**
 - Makes ice during less expensive time of day
 - Flattens out the demand curve
- **Chilled Water**
 - Supplemental cooling
 - Supplemental dehumidification
- **Boilers**
 - Perimeter heating
 - Supplemental heating

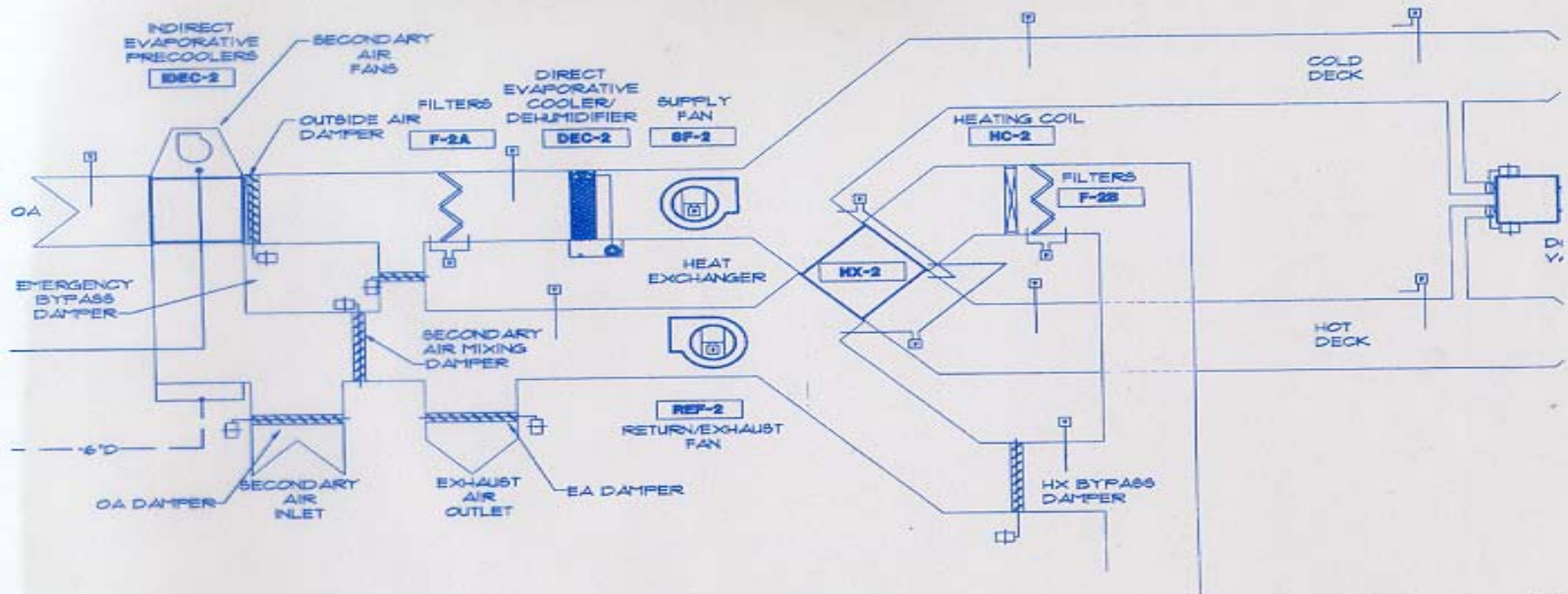


Evaporative Cooling: Hybrid (Multi-Functional) System

- **Heating Coil**
 - Pre-heat (on building exhaust)
 - Supplemental heat
 - Defrost (for IDEC)
- **Filtration**
 - Supply
 - Exhaust
- **Water Treatment**
 - Ozonation
 - Pulsed Power

Evaporative Cooling: Hybrid (Multi-Functional) System

DUAL DUCT MULTI-ZONE WAUSAU SCHOOL DISTRICT (WISCONSIN)



1) Energy Efficiency is greatly enhanced through the use of evaporative coolers and air-to-air heat exchangers.

2) IAQ is improved by the use of large quantities of outdoor air and through the washing of the supply air inside the DEC unit which extracts condensable gases responsible for sick building syndrome and which cannot be removed by conventional filters.

3) Hydronic perimeter heating is used to prevent building heat loss.

4) Dual-Duct VAV boxes are used to provide cooling to the individual building zones.

5) Very inexpensive cooling is provided by the IDEC(idec-2) unit which provides first stage cool, and the DEC(dec-2) unit which provides second stage cooling.

6) Auxilliary cooling can be added in the

future - if needed - by using a chill cool supply water (through a secor heat exchanger loop) before enteri DEC unit.

7) The HX (hx-2) heat exchanger free heating for the hot deck. In h-weather, the HX is bypassed.

8) The heat exchanger located wit IDEC recovers heat and cooling fr building exhaust.

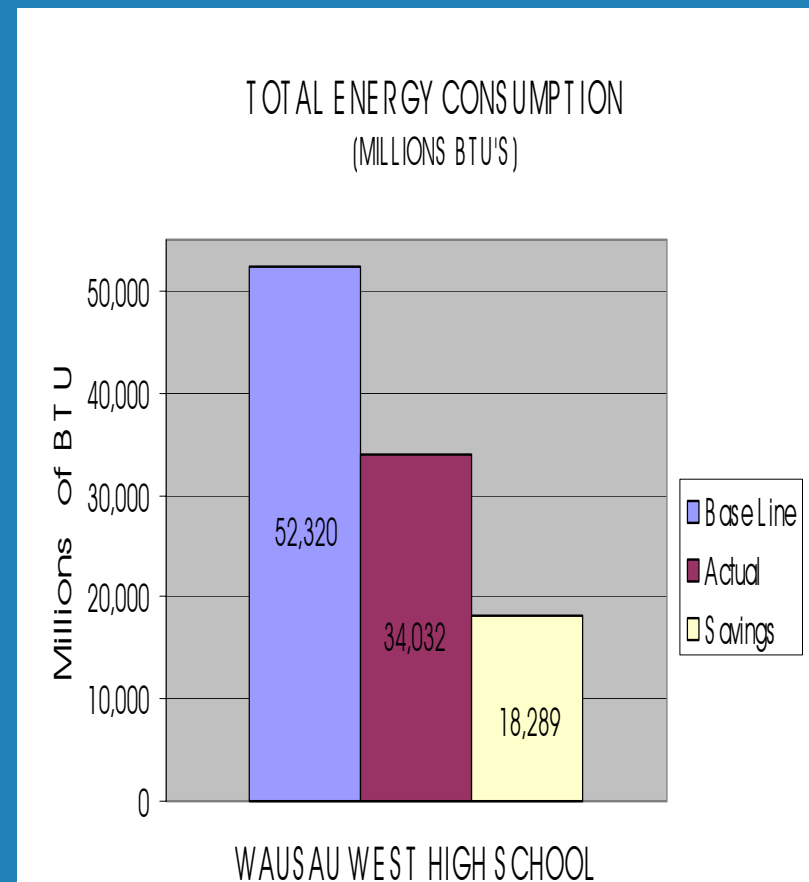
Evaporative Cooling: Hybrid (Multi-Functional) System

∩ Wausau West High School

- ∩ Area: 275,000 S/F
- ∩ System Type: Regenerative Double Duct
- ∩ Primary Heating Plant Reduction: 60%
- ∩ Primary Cooling Plant Reduction: 92%
- ∩ Gross Energy Use Reductions:
 - Natural Gas: 38%
 - Electricity (kWh): 27.8%
 - Electrical Demand: 25%
- ∩ Gross Energy Cost Reductions: 29.3%

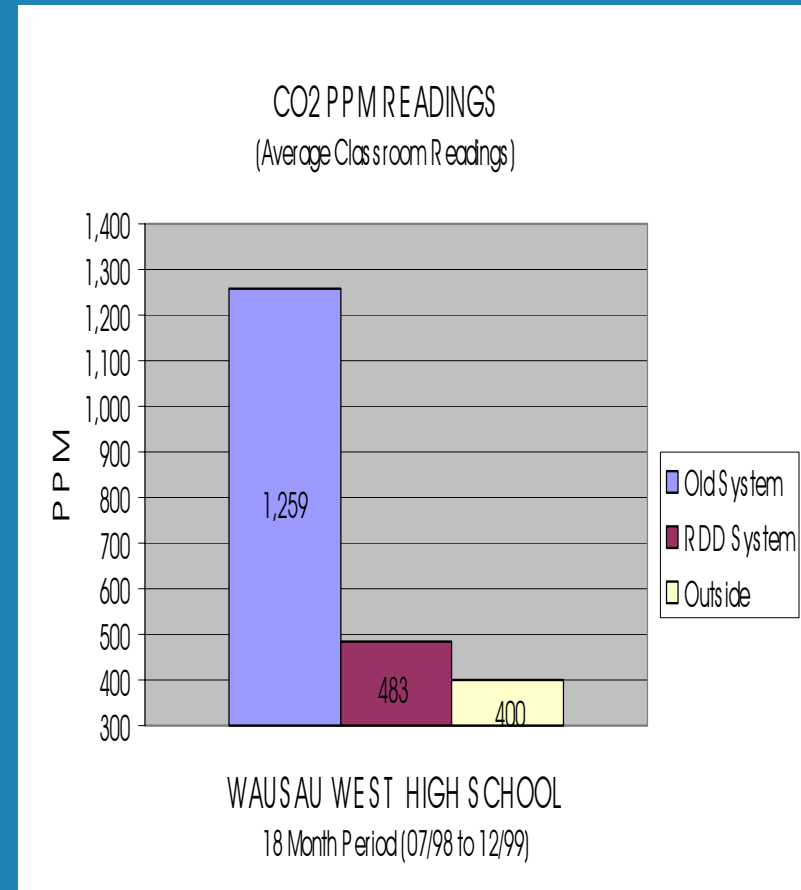
Evaporative Cooling: Hybrid (Multi-Functional) System

- ∞ “Base Line” energy consumption based on the former HVAC system that utilized **minimum outside air** and recirculated a majority of existing building air
- ∞ “Actual” energy consumption based on the new **100% outside air HVAC** system



Evaporative Cooling: Hybrid (Multi-Functional) System

ASHRAE Standard 62.1-2001 uses an indoor to outdoor differential concentration not greater than 700 ppm of CO₂ as an indicator of acceptable indoor air quality



Evaporative Cooling: Hybrid (Multi-Functional) System

Advantages to the Hybrid system:

- Lower first cost (especially for new construction)
- Reduced energy usage (up to 70%)
- Improved indoor air quality
 - Larger amounts of outdoor air
 - Direct section acts as an air scrubber

EXCELLENCE IN INNOVATION AWARD Wisconsin Energy Initiative 2



Energy Efficiency
Air Quality
Comfort

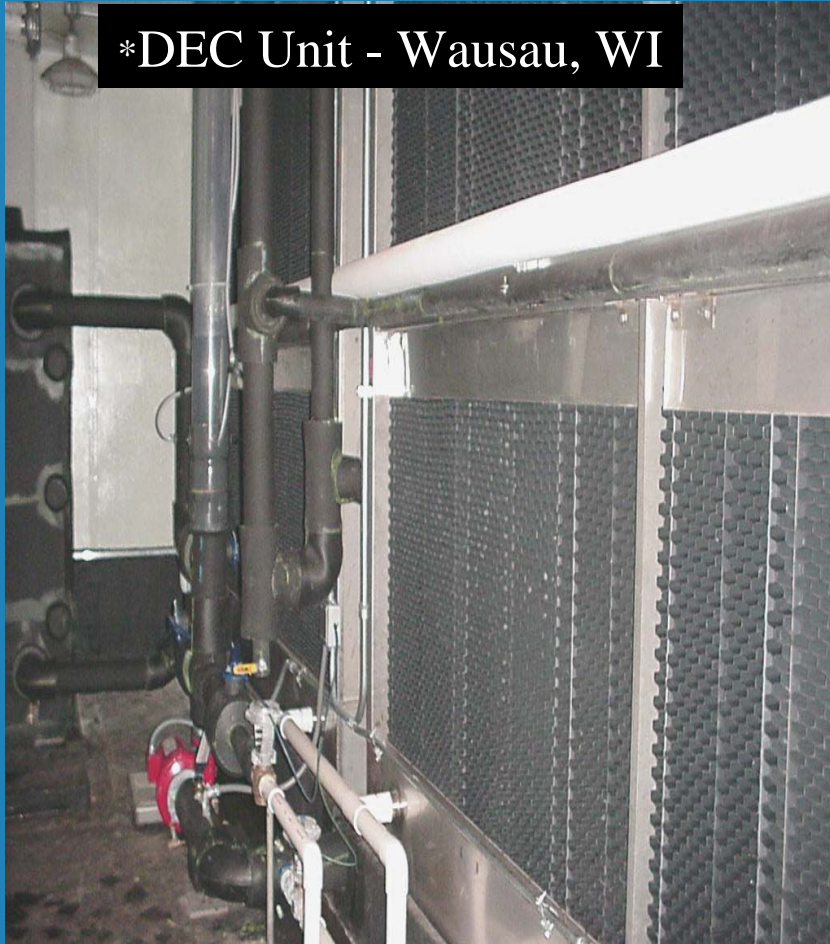
Evaporative Cooling: Hybrid (Multi-Functional) System

*IDEC Units - Wausau, WI



Evaporative Cooling: Hybrid (Multi-Functional) System

*DEC Unit - Wausau, WI



*70-Ton Chiller - Wausau, WI



Evaporative Cooling: Hybrid (Multi-Functional) System

*IDEC Unit - Wausau, WI



*Ozonation - Wausau, WI



Evaporative Cooling: Hybrid (Multi-Functional) System

*Boilers - Wausau, WI

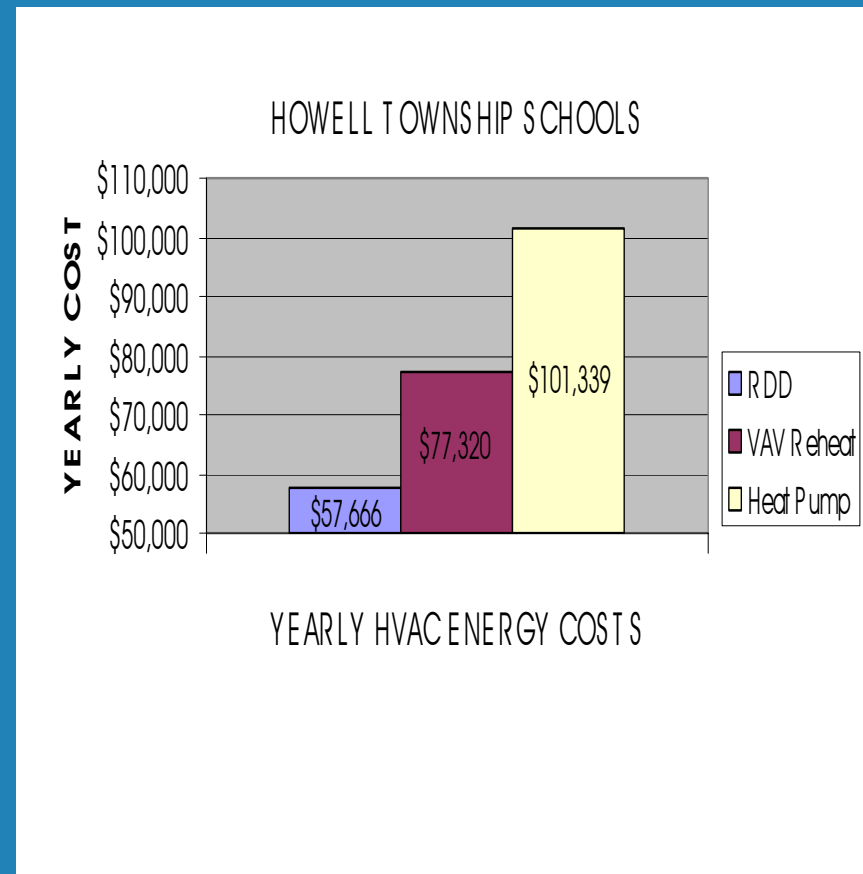


*Thermal Storage - Wausau, WI



Evaporative Cooling: Hybrid (Multi-Functional) System

- Independent study commissioned by a New Jersey utility company comparing 3 proposed HVAC systems for 3 new schools
- With the Regenerative Double Duct™ HVAC design, these 3 schools will become the first LEED silver certified schools in New Jersey



Evaporative Cooling: Hybrid (Multi-Functional) System

*IDEC unit - Howell Township, NJ



Evaporative Cooling: Hybrid (Multi-Functional) System

*Thermal Energy Storage - Howell Township, NJ



Evaporative Cooling: Hybrid (Multi-Functional) System



Evaporative Cooling: Hybrid (Multi-Functional) System

*Boilers - Howell Township, NJ

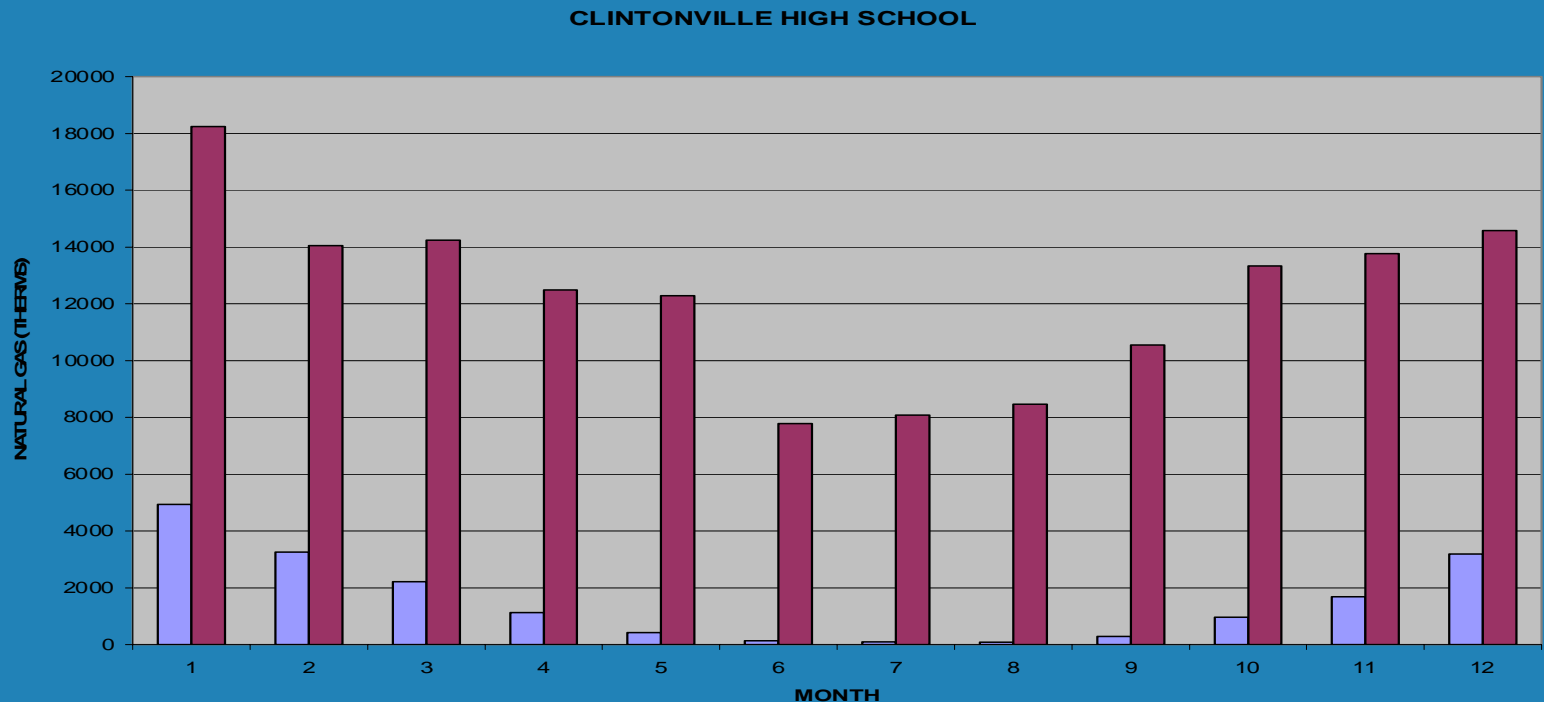


*Pulsed Power Water Treatment



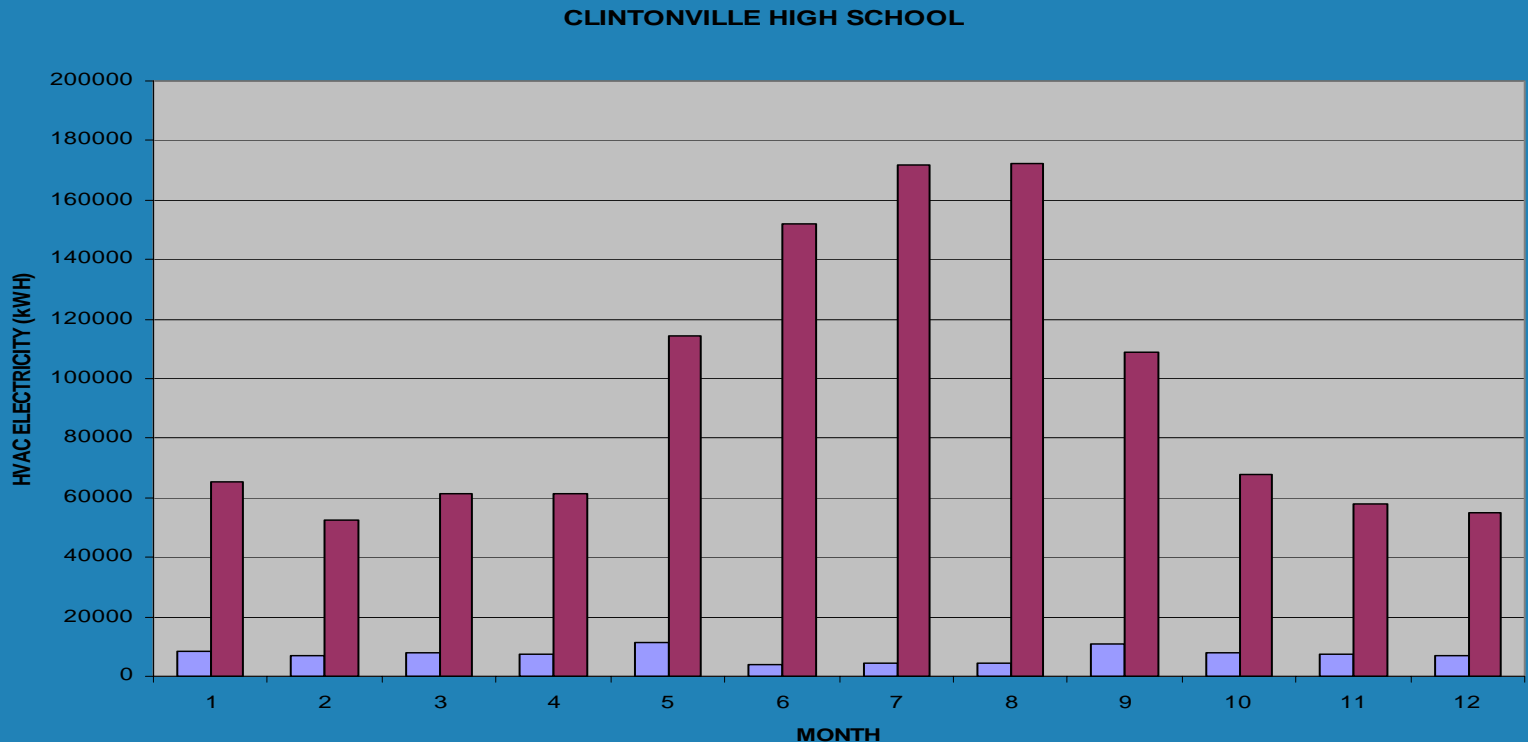
Evaporative Cooling: Hybrid (Multi-Functional) System

*Clintonville High School: Natural Gas Use
(Projected Energy Consumption Using the Regenerative Double Duct™
Compared to Gas Absorption Chillers and Boilers)



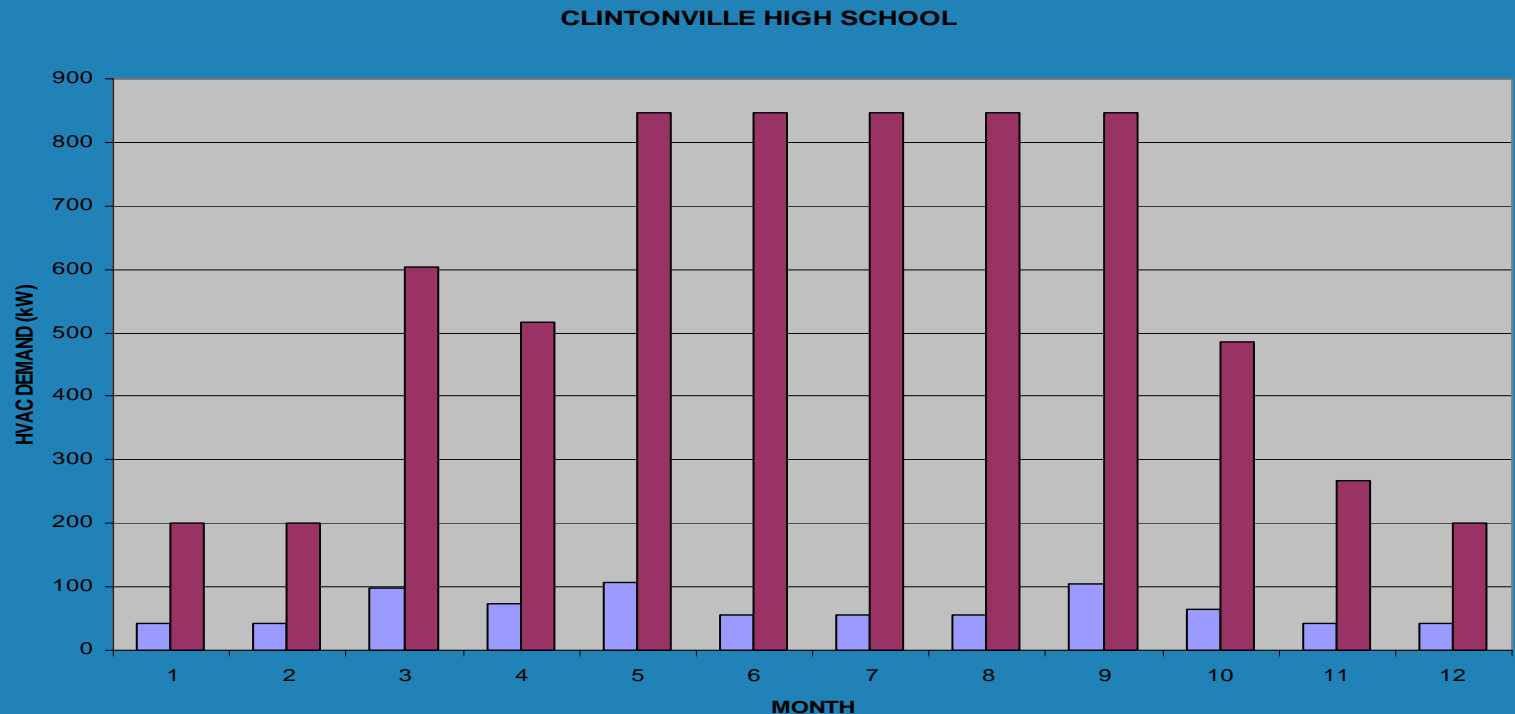
Evaporative Cooling: Hybrid (Multi-Functional) System

*Clintonville High School: Electrical Use
(Projected Energy Consumption Using the Regenerative Double Duct™
Compared to Gas Absorption Chillers and Boilers)



Evaporative Cooling: Hybrid (Multi-Functional) System

*Clintonville High School: HVAC Demand
(Projected Demand Using the Regenerative Double Duct™ Compared
to Gas Absorption Chillers and Boilers)



Evaporative Cooling: Hybrid (Unitary/Integrated) System

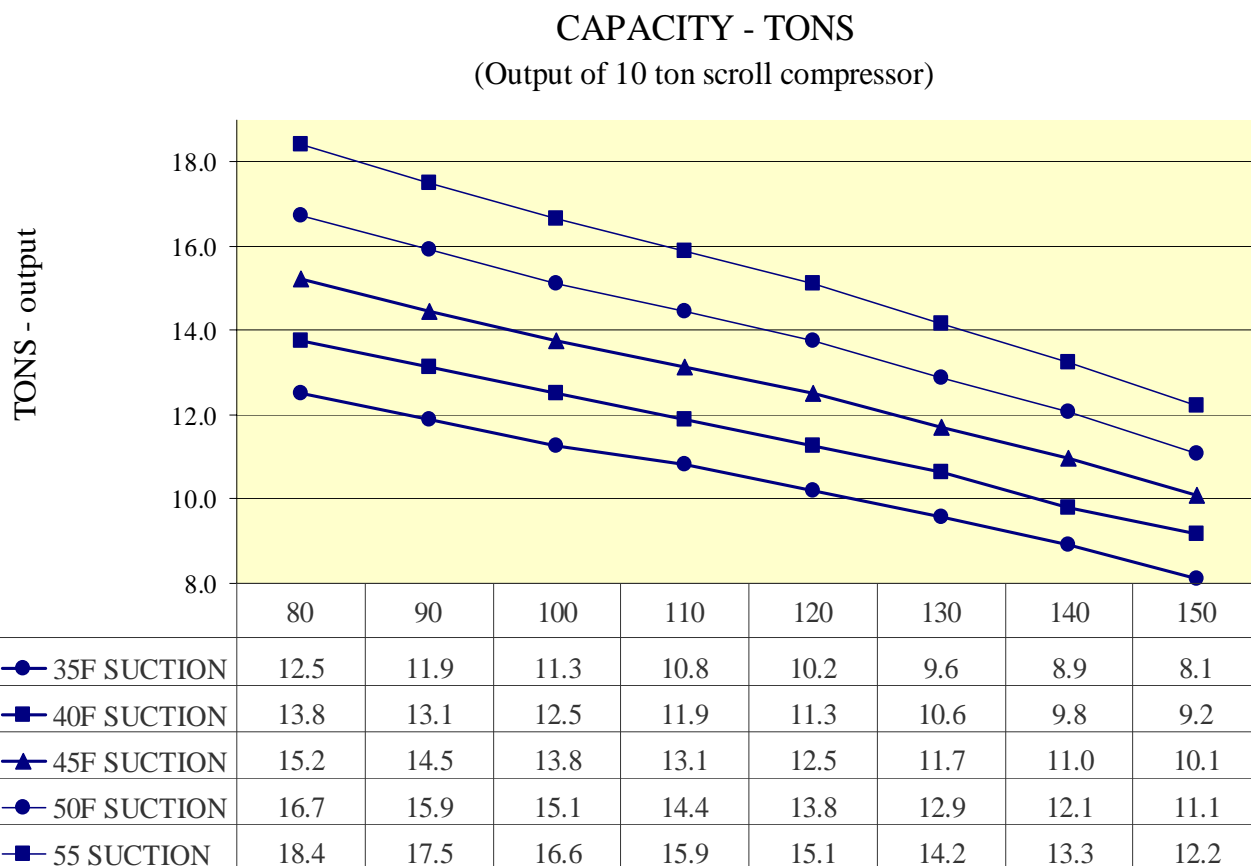
∞ Roof-top units can be designed with many of the same components and efficiencies of the built-up systems

- Indirect evaporative precooling/preheating
- Direct evaporative cooling/humidification
- Evaporative condenser
- Downsized centrifugal compressor and cooling coil
- Downsized hot water coil or furnace

Evaporative Cooling: Hybrid (Unitary/Integrated) System

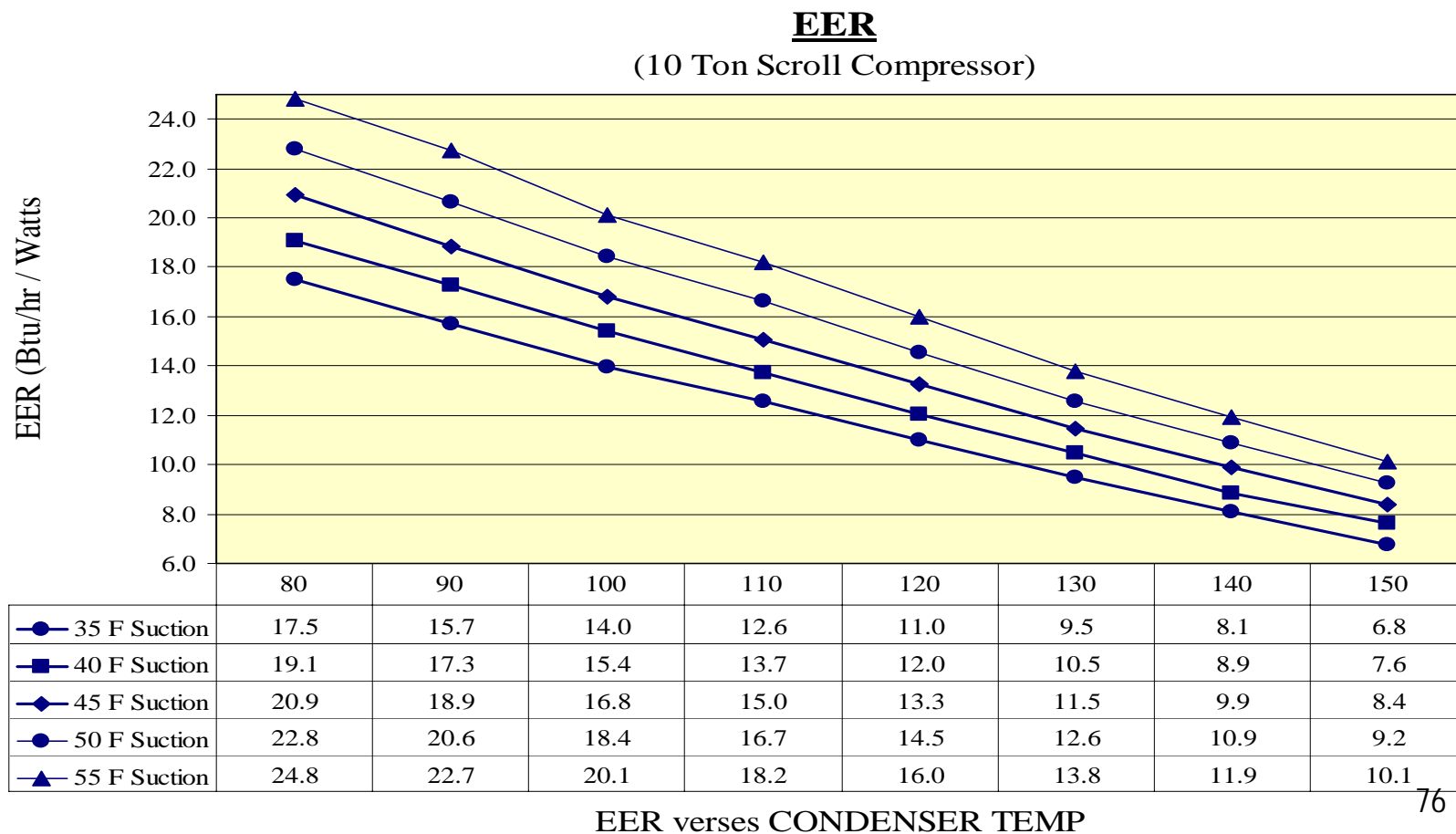
***ARI** conditions:
130°F condensing
and 45°F suction
temperatures.

***ADA Systems'**
new hybrid
design will have
operating
conditions of
90°F condensing
and 50°F suction
temperatures.



OUTPUT TONS verses CONDENSING TEMP

Evaporative Cooling: Hybrid (Unitary/Integrated) System



Evaporative Cooling: Conclusions (Part 1)

∞ Classical HVAC system strategies and equipment are not meeting the client's needs. Classical HVAC solutions are the problem

- They are primarily constructed around energy intensive processes
- Reliance on ventilation reduction is the primary cause of air quality problems
- Recirculation compromises indoor air quality and energy efficiency
- They place indoor air quality and energy conservation goals in fundamental conflict

∞ New HVAC system strategies are needed...better engineering is required

Evaporative Cooling: Conclusions (Part 2)

- ∞ Truly “green” HVAC systems are attainable with simple technologies that are readily available
- ∞ Benefits of these “green” systems
 - Competitive construction costs
 - improved indoor air quality
 - reduced energy consumption
 - reduced heating/cooling plants
 - easy to maintain
- ∞ Both Direct and Indirect evaporative cooling are simple, reliable processes which will take you where you want to go